

National Aeronautics and Space Administration



TECHNOLOGY INNOVATION

MAGAZINE FOR BUSINESS & TECHNOLOGY

Volume 15 • Number 3 • 2010

**NASA–NIH Agreement
Opens Doors to
Medical
Research on
Space Station**

HEALTH & MEDICINE



NASA Technologies Improve Health Care in Space and on Earth

PLUS

Innovations to Protect
Astronauts Provide
Earthly Benefits in:

- Cardiology
- Imaging
- Radiation Risks
- Infectious Diseases
- Behavioral Health
- Aging-related Conditions

How You Can Participate in the Space Program

Centennial Challenges

<http://www.nasa.gov/challenges>

August 13, 2010: Strong Tether

Seattle, WA

2010 PURSE: \$2,000,000

Super-strength materials

Managed by: Spaceward Foundation

<http://www.spaceward.org/elevator2010-ts>



Fall 2010: Power Beaming

Location TBA

2010 PURSE: \$1,100,000 REMAINING

Wireless power transmission

Managed by: Spaceward Foundation

<http://www.SpaceElevatorGames.org>



Coming in 2011:

Green Flight

Sonoma County Airport, Santa Rosa, CA

PURSE: \$1,650,000

Safe, quiet & super-efficient aircraft

Managed by: Comparative Aircraft Flight Efficiency Foundation

http://cafefoundation.org/v2/gfc_main.php



New! **Nano-Satellite Launch Challenge** Location TBA

PURSE: \$2,000,000

New! **Night Rover Challenge** Location TBA

PURSE: \$1,500,000

New! **Sample Return Robot Challenge** Location TBA

PURSE: \$1,500,000

\$3.65 Million Awarded in 2009!

Check Web Site for Details: <http://www.nasa.gov/challenges>

LAUNCH: Health

<http://www.launch.org>

Seeking 10 transformative innovations poised to improve health and quality of life on Earth. Specifically interested in solutions that address first 20 years of life.

Providing and improving access to:

- Nutrition and food
- Physical activity
- Preventive health care

LAUNCH is a partnership among NASA, the U.S. Agency for International Development (USAID), the U.S. Department of State and NIKE.

Please visit <http://www.launch.org> for more information.

COVER STORY



PAGE 9

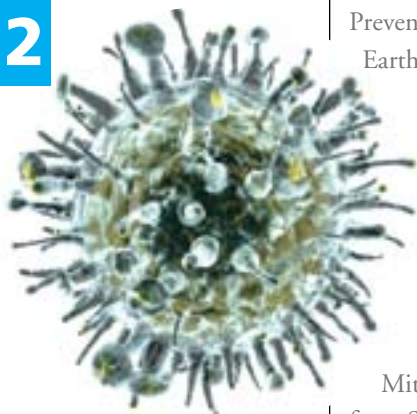
SPACE STATION AGREEMENT OPENS SPACE TO ADVANCE HEALTH & MEDICINE RESEARCH

BY NEAL PELLIS, PH.D.

NASA and the National Institutes of Health are working together on research projects of common interest and using the International Space Station National Laboratory for research that will benefit health care on Earth.

feature articles

12



12 INFECTIOUS DISEASES

Early Detection of Immune Changes Prevents Painful Shingles in Astronauts & Earth-Bound Patients

16 AGING

NASA Technologies Address the Aging Population

20 RADIATION RISKS

Mitigating Astronauts' Health Risks from Space Radiation

24



24 CARDIOLOGY

Space Technology to Maintain Cardiac Health & Performance

28 IMAGING

Advanced Ultrasound for the Space Program and On Earth

32 BEHAVIORAL HEALTH

Behavioral Health & Performance Tools to Reduce Astronauts' Risks

16



28



departments

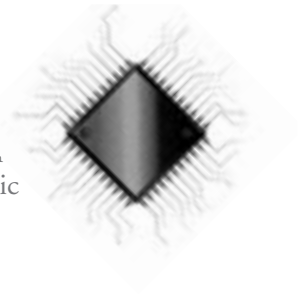
To view online and for past issues, visit <http://www.ipp.nasa.gov/innovation>

6 NASA NEWS BRIEFS

- Helping the Smallest of Mankind
- Dr. Robert D. Braun Leads NASA's Office of Chief Technologist
- NASA Partners with McCord Foundation on Buruli Ulcer Treatment

36 TECH TALK

- Bioscience Benefits from NASA Laser Atmospheric Tool



38 INNOVATOR'S CORNER

- National Space Biomedical Research Institute: Conducting "Down-to-Earth" Space Research in Health & Medicine



42 FACILITY FOCUS

- Biomedical Laboratory Tackles Health & Safety Issues



44 INFUSION

- From Snow to Space, Cell Imaging Finds Its Place at NASA



46 INNOVATIVE RESEARCH

- Open Innovation: A New Business Model for NASA's Space Life Sciences Directorate

48 OPPORTUNITIES FOR PARTNERSHIP

- Nanotechnology for Encapsulation of Implantable Medical Devices
- Perilog - A Contextual Search Method for Improving Search Results
- Endothelium Preserving Microwave Treatment for Atherosclerosis
- *In Situ* Health Monitoring of Piezoelectric Sensor

53 NASA IPP NETWORK

- Directory of NASA's Innovative Partnerships Program National Offices, and Affiliated and Allied Organizations

Material from this publication may be reproduced without the permission of the publisher.

CHIEF EDITOR
Janelle Turner
NASA

MANAGING EDITOR
Kathryn Duda
National Technology
Transfer Center

ART DIRECTOR/PRODUCTION
Dennis Packer
National Technology
Transfer Center

CONTRIBUTING AUTHORS
Donna P. Anderson
David Basiji, Ph.D.
Sheri Beam
Nathan Bramall, Ph.D.
Robert D. Braun, Ph.D.
Anna Bui
James Cartreine, Ph.D.
Francis A. Cucinotta, Ph.D.
Jeffrey R. Davis, M.D., Ph.D.
David Dinges, Ph.D.
Donald Doerr
Scott A. Dulchavsky, M.D.
Carol Anne Dunn
Kathleen Garcia
Dennis J. Grounds
Douglas Hamilton, M.D., Ph.D.
Karim R. Lakhani, Ph.D.
Lauren Leveton, Ph.D.
Satish K. Mehta, Ph.D.
Shannon Melton
C. Mark Ott, Ph.D.
Neal Pellis, Ph.D.
Duane L. Pierson, Ph.D.
Elizabeth E. Richard
Debbie Rivera
Raphael Rose, Ph.D.
Ashot E. Sargsyan, M.D.
Victor Schneider, M.D.
Gary Strangman, Ph.D.
Jeffrey P. Sutton, M.D., Ph.D.

Technology Innovation is
published by the NASA Innovative
Partnerships Program.
Your feedback provides
important contributions
to this publication.

A Message from NASA

UPFRONT with...

Robert D. Braun, Ph.D.

Chief Technologist, NASA



Welcome to *Technology Innovation*!

We are particularly proud of this issue as it focuses on the contributions that NASA and its partners are making to the health and well-being of our astronauts and society as a whole. With healthcare at the forefront of public interest, it is especially relevant that we tell you about some of the NASA innovations that are under development in this area.

In this issue, you will learn of new NASA-based medical technologies that have entered the picture recently, as well as many that are in development and that could one day transform our health and medical care. Procedures like a test to diagnose shingles at an earlier stage, so that treatment can begin before painful lesions develop. And a method of decontaminating orthopedic implants to reduce the chances of inflammation, pain and implant failure. Even wearable neuroimaging devices that check for disease in active and mobile patients.

As a research and development agency, NASA plays a vital role in America's innovation engine and, as such, its future economic prosperity. By focusing on innovation and technology, NASA will drive a sustainable, yet aggressive, future mission portfolio, enabling new approaches to its current missions and entirely new science and exploration endeavors. This investment also will allow NASA to participate in the development of technological solutions addressing broader national needs in health and wellness, energy, weather and climate and national security.

Central to NASA's innovation initiative is the new Space Technology program that builds off of the success of the NASA Innovative Partnerships Program to meet the Agency's needs for a broad range of technological solutions, as well as meeting the needs of other government agencies and the Nation's space industry. This NASA program competitively sponsors a range of concept and initial technology development efforts across academia, industry and the NASA Centers; matures advanced technologies that have the potential to revolutionize future space missions; and proves technologies that are of benefit to multiple customers in the flight-relevant environment of space.

I believe a NASA focused on innovation and technology unleashes a range of exciting potential futures for our Nation's civil space program, particularly where these innovations lead to advancements in health and medicine. Through this renewed focus, I believe NASA can be an important catalyst for economic expansion in this Nation.

You will be hearing more about the new Space Technology program and our initiatives in future issues of *Technology Innovation*.

In the meantime, I invite you to enjoy reading about how NASA and its partners are working together to improve health care in space and on Earth. We hope you will share our anticipation and excitement as we progress into a new era of innovation.

Helping the Smallest of Mankind

Weighing not much more than a pound and often less, neonatal infants are getting a high-tech assist from engineers at NASA.

NASA's Johnson Space Center (JSC) and Texas Children's Hospital in Houston recently signed a Space Act Agreement to further solidify the engineering research and development project on the effects of vibrations on neonatal infants in transport. This collaborative effort began nearly three years ago through the Space Alliance Technology Outreach Program (SATOP).

Sick premature babies often are transported to tertiary care centers when they require a level of care that exceeds that which is able to be delivered at their birth hospital. While such transports are necessary, the procedures involved in transport of such fragile infants inevitably disturb the infants' systems, which may result in adverse short- and long-term outcomes, explains Jack A. Klasen of Texas Children's Hospital.

Prior to the hospital's work with NASA's vibration lab at JSC, very little study had been conducted on the role of vibration in neonatal transport. The initial request from Texas Children's Hospital through SATOP was for engineering assistance, to determine where to position sensors to measure vibrations



JOHNSON SPACE CENTER AND TEXAS CHILDREN'S HOSPITAL ARE PARTNERING ON RESEARCH TO DETERMINE THE EFFECTS OF VIBRATIONS ON NEONATAL INFANTS IN TRANSPORT BY AMBULANCE, LIFE FLIGHT HELICOPTER AND JET.

during transport. This included multiple forms of ground and air transport, such as ambulance, Life Flight helicopter and jet. The work with JSC's engineers now includes developing a test design for vibration, performing the testing at the space center and collaborating with JSC experts on data analysis.

Kathryn Turner, a NASA project manager with a background in biomedical engineering, was working on developing a method of using a wireless network of instruments to monitor vibration onboard the International Space Station when Texas Children's Hospital approached the Agency asking for help. She and a JSC engineering team adjusted the technology for

use on carts used to transport infants, and from there a relationship developed that has since grown to include having the JSC vibration laboratory study the carts themselves.

"It's impossible to see those children and not want to move heaven and Earth to serve them. We're fortunate to have the skill set they need," says Turner.

The JSC team is led by Peter Fantasia, and, in addition to Turner, includes Scott West, Mike Grygier, Ph.D., and Costas Christofi, Ph.D. West discusses that it is a collaborative effort including many others in the branch as their individual areas of expertise are needed. He adds, "The work is, of course, interesting,

as most all engineering problems are interesting and challenging – but this one is special because we get to take our branch’s combined knowledge of vibration, modeling and isolation methods that we normally apply to spacecraft, launch vehicles and avionics, and try to help the most helpless among us.”

“Currently there are no medical or industry standards to tell us how much vibration is acceptable for fragile critically ill neonates to withstand,” Klasen says. “What leaps out at you when you are working with Johnson Space Center engineers is the incredible source of knowledge they have. It is impressive.”

Bay Area Houston Economic Partnership, in partnership with the JSC, has hosted SATOP since November 1998. “The program has had tremendous success operating within the Houston Metropolitan Area and is expecting even greater results out of its statewide expansion. The SATOP program under BAHEP has helped more than 600 Texas businesses with free engineering assistance since its inception,” says Nick Gardner, SATOP program manager. ■

By Donna Anderson, APR, Advanced Planning Office, Johnson Space Center

For more information on the vibration study, contact Peter Fantasia at peter.m.fantasia@nasa.gov.

Please mention that you read about it in Technology Innovation.

Dr. Robert D. Braun Leads NASA’s Office of Chief Technologist

Robert D. Braun, Ph.D., was appointed Chief Technologist by NASA Administrator Charles F. Bolden in February. He serves as the principal advisor and advocate on matters concerning Agency-wide technology policy and programs. Beginning this fall, NASA’s Innovative Partnerships Program will become part of the Office of the Chief Technologist, led by Dr. Braun.

Dr. Braun’s appointment comes as NASA launches a bold new initiative targeting technologies that could be transformational in their ability to improve the capability, reduce the cost and expand the reach of future human and robotic missions.

He will lead development of a suite of advanced aerospace system concepts and technology development programs leading to new approaches to future NASA missions and solutions to significant national needs.

During the coming decade, NASA will increase its support for research in advanced concepts and critical enabling technologies, including a steady cadence of laboratory, ground-based, and flight-test programs. This approach will also generate spin-off technologies and potentially entire new industries.

“Bobby brings expert knowledge of spacecraft, robotic and planetary

exploration technology development to this new position,” Bolden said upon making the appointment. “His experience working at NASA Langley and in the academic community brings an excellent skill mix to this exciting and challenging new job.”

Dr. Braun has more than 20 years experience performing design and analysis of planetary exploration systems as a member of the technical staff at NASA’s Langley Research Center and the Georgia Institute of Technology. His research has focused on systems aspects of planetary exploration, where he has contributed to the design, development, test and operation of several robotic space flight systems. He was a member of the Mars Pathfinder design and landing operations team and was on the development teams for several Mars projects.

Dr. Braun received a B.S. in aerospace engineering from Penn State, a M.S. in astronautics from the George Washington University and a Ph.D. in aeronautics and astronautics from Stanford University. He is an author of more than 175 technical publications. ■

NASA Partners with McCord Foundation on Buruli Ulcer Treatment

NASA science, technology and innovation, together with the McCord Research Foundation, may help develop efficient solutions to the cause and treatment of

NASA News Briefs

CREDIT: MCCORD FOUNDATION



A NASA-DESIGNED PORTABLE HYPERBARIC CHAMBER MAY BRING RELIEF TO VICTIMS OF BURULI ULCER IN REMOTE REGIONS OF THE WORLD.

Buruli Ulcer, a devastating skin disease. Discussions for a strategic alliance are underway currently by investigating how remote sensing, engineering of hyperbaric treatment and water filtration innovations, will not only improve ongoing research and applicability for NASA's missions, but help this global medical concern as well.

The McCord Research Foundation, under the leadership of founder Darlene McCord, Ph.D., reached out to NASA in hopes of forming a strategic alliance to retrieve data based on new environmental and hyperbaric technologies. The McCord Foundation's objective is to find a source of a bacterium that causes Buruli Ulcer. This disease affects primarily children under 15 years of age and has appeared in more than 30 countries, with the potential for spreading, even to the U.S. The NASA team saw several opportunities

where advances in NASA research and technologies could be demonstrated and tested in conjunction with the McCord research.

Buruli Ulcer is caused by the bacterium *Mycobacterium ulcerans*, which is a genetic cousin to the bacterium that causes leprosy and tuberculosis. In two African countries alone, some 4,000 known new cases appear each year. Buruli Ulcer is found mostly in tropical and subtropical areas such as Australia, East Africa, West Africa, and Central and South America.

Buruli Ulcer has a dramatic impact. According to Dr. McCord, a child can be removed from school, family and friends and hidden away because of an open sore that appears on an arm or leg.

Gathered at that first meeting were NASA representatives from multiple programs and Centers: scientists, medical personnel, Innovative Partnerships Program specialists and communication experts. All listened to a description of this medical plight and together determined ways that NASA research, results and passion could help Dr. McCord and her team bring relief to these young victims. Dr. McCord developed a skin wound treatment for the ulcers that is now in medical trials. The treatment is most effective, however, when the ulcers remain small.

Hyperbaric oxygen therapy (breathing pure oxygen while in a pressurized chamber) is an effective way to minimize the spread of the ulcer, as it greatly increases the concentration of oxygen to the blood and wound. Increasing the amount of oxygen in

bodily tissues greatly increases the ability of white blood cells to combat and control bacterial infections, and it promotes the tissue-healing processes.

NASA has developed hyperbaric chambers for astronauts in space to counter the effects of decompression sickness. Decompression sickness, commonly called "the bends," can occur in astronauts as they undergo pressure changes returning from spacewalks, similar to divers as they return to the water's surface. NASA's James Locke, M.D., based at the Johnson Space Center, recently designed a portable hyperbaric chamber that can increase an astronaut's tolerance of G-forces and acceleration during long-term space travel. This chamber could potentially be tested in remote regions in which many of these young victims live.

An alliance between NASA and the McCord Foundation is another way for the Agency to innovatively apply NASA research and technology. As with any NASA endeavor, all knowledge gained in scientific and technical areas may lead to other technologies and results that could be applied to the secondary use of helping improve the quality of life on Earth. ■

*By Debbie Rivera, Strategic Alliances,
NASA Headquarters.*

*For more information about the
McCord Foundation's efforts to
prevent and treat Buruli Ulcer, visit
www.mccordresearch.com/buruli-project.html.*

HEALTH & MEDICINE

Space Station Agreement Opens Space to Advance Health & Medicine Research



By Neal Pellis, Ph.D.
NASA Johnson Space Center

NASA has a long history at the forefront of research and development that advance the field of health and medicine on Earth. This leadership role continues with an agreement between the Agency and the National Institutes of Health (NIH) that was launched two and a half years ago and is about to progress to a new and significant level. The eventual results may vastly broaden medical research

to benefit Americans for generations to come.

In September 2007, NASA and the NIH signed a landmark Memorandum of Understanding (MOU) agreeing to work together on research projects of common interest, and to use the International Space Station (ISS) National Laboratory for research that serves the NIH mission. On the heels of this agreement, the NIH issued a solicitation for proposals to use

the space environment to probe biological systems that reveal fundamental mechanisms addressing the health of humans on Earth. The first phase of these studies is to be ground-based experiments that define the profile of the flight experiments. This first solicitation concentrates on the use of cellular models of human disease to probe the role of physical forces in cell physiological processes. Awards will be made in early summer of this year.

The MOU with NIH, the ensuing solicitation and the ISS National Lab open the space environment to a vast community of scientists and set the stage for an era of learning the role of physical forces such as gravity in life processes. Adaptation of living systems to microgravity and possibly the high energy radiation of space will help us understand how these novel mechanisms work. Knowledge of these mechanisms not only provides understanding of the basis of cell processes, it also opens new vistas for development of applications for human health and exploration of the solar system, and beyond.

The NIH team, headed by Stephen Katz, M.D., Ph.D., director of the National Institute of Arthritis, Musculoskeletal, and Skin Diseases (NIAMS), negotiated the MOU with the NASA team headed by Mark Ufran of the ISS Program Office. Based on the interest of eight other institutes in participating in the solicitation and use of the ISS National Lab resources, NIH moved forward to solicit research proposals from the U.S. science community.



RESPONDING TO MEDIA QUESTIONS AFTER THE SIGNING OF THE MEMORANDUM OF UNDERSTANDING BETWEEN NASA AND THE NIH IN SEPTEMBER 2007 WERE NASA ASSOCIATE ADMINISTRATOR FOR SPACE OPERATIONS WILLIAM H. GERSTENMAIER, FORMER ASTRONAUT COLONEL CARL E. WALZ (USAF, RET.), NICHD SCIENTIST JOSHUA ZIMMERBERG, M.D., PH.D., AND NIAMS DIRECTOR STEPHEN I. KATZ, M.D., PH.D.

A National Lab for the U.S. Scientific Community

The declaration of a portion of the ISS resources as National Lab status opened the resources to other federal agencies, academic institutions and industry. With an established allocation of space and resources in the ISS that can be used to support their research, the NIH commenced to communicate the opportunity to the entire biomedical science community. The landmark agreement brings a large community of scientific expertise to microgravity research. An expanded expertise base brings with it new opportunities for Earth-based applications as well as for space exploration.

Maintaining humans in space and on other planetary surfaces levies substantial challenges for the development of health care equipment and procedures that meet the requirements and conditions of space exploration.

Having met the stringent require-

ment of small-mass, low-power demand, and durability for space, some of these developments make their way into Earth-based applications. The sophisticated telemetry that is used to monitor patients in hospitals today had its start in the Apollo program, where cardiac monitoring of the crew was transmitted in real time to Earth. Today, non-invasive technologies for a multitude of physiological functions are in development by NASA and many different commercial partners.

Similarly, the complex laboratory analyses in clinical and research labs are being miniaturized and conformed to space requirements and no doubt will make their way into standard clinical use on the ground.

In research, most advancements are products of years-long efforts to understand the basis of disease; formulate a treatment strategy; test in culture, animals and then human trials; and finally receive approval for use in clinical diagnosis and treatment.

CREDIT: NATIONAL INSTITUTES OF HEALTH

Science is at the beginning of understanding the role of physical forces in life processes and dysfunction. The ISS National Laboratory provides the most unique opportunity to investigate the role of these physical forces, as space research examines the response of life to diminished gravity. Moreover, scientists can use the microgravity environment as a tool to unmask functions and processes obfuscated by gravity. In other words, without gravity, other forces take on a more dominant role and therefore are more apparent in their influence on life.

Research and technology developments at NASA have had significant impact on health care on Earth. A recent example of how studies aboard the ISS can lead to groundbreaking health advances is the *Salmonella* research done over the past few years. This bacterium, which causes one of the most common forms of food poisoning in the United States, is a major cause of infant mortality worldwide.

Studies in 2006 and 2008 found that *Salmonella* cultured in the microgravity environment of space were more virulent than those on Earth. Results brought back from space were used in later experiments, which found that adjusting the ion content of the bacteria's environment turns off the virulence effect.

Discovering the factors like these that are responsible for growth and virulence of bacteria will contribute to the development of novel therapeutic treatments, including vaccines.

In August 2009, Space Shuttle Discovery carried experiments from Astrogenetix (www.astrogenetix.com) to the ISS, allowing the Austin, Tex.-based

company to use the station's unique microgravity environment to conduct additional research, which resulted in the discovery of a potential candidate vaccine for this pathogen.

Studies on bacterial virulence have been extended to Methicillin-resistant *Staphylococcus aureus* (MRSA), a bacterium that is unresponsive to commonly used antibiotics and typically causes infections, including pneumonia. MRSA is responsible for more than 19,000 deaths annually

These and many other studies have been conducted over the past several years during ISS assembly. Now completed, and with a full cadre of astronauts devoted to health and medical research, great things no doubt lie ahead.

In the early phase of its participation, NIH will use the ISS National Laboratory to investigate specific disease processes in cells using the microgravity environment to reveal novel mechanisms that scientists can use as targets for drug development. In addition to space research, NASA developed a cell culture system that provides an analog for scientists to use in developing hypotheses to be tested in space. The system, known as the NASA bioreactor produced and sold by Synthecon Inc., Houston, Tex., mimics some characteristics of space, and its use in research increases the prospect for successful space experiments.

This particular technology emerged only because there is a space program. One of its original purposes was to keep cells suspended until they reached space. It turned out to have wide ground-based application and will be essential to the NIH research effort. Also, the bioreactor has

become a widely used tool for ground-based research in tissue engineering, cell-cell interaction studies, promoting maturation (differentiation) of specific cell lineages and deployment of contractile elements within cells that effect cellular movement. Each of these major areas is of interest in many disease processes and therefore can be the subject of NIH-sponsored research in the National Laboratory.

NASA's agreement with NIH is the first of more to come, as other federal agencies express interest in working with NASA and in pursuing their own research goals, using the new tool of microgravity to probe life processes and to open new pathways to research and technology development in science and human health.

The use of the National Lab comes at a time when transportation to the ISS will undergo substantial change. Indeed, the potential large customer base for transportation to and from the ISS can enhance the potential for development of multiple transport venues. Some of these no doubt will be provided by commercial carriers. This flagship agreement with the NIH serves as the nucleus for growing the community of science and engineering to help meet the nation's future demands in technology, human health and space exploration. ■

Neal Pellis, Ph.D., is senior scientist in Space Life Sciences at Johnson Space Center.

For more information, contact him at neal.r.pellis@nasa.gov.

Please mention that you read about it in Technology Innovation.

Early Detection of Immune Changes Prevents Painful Shingles in Astronauts & Earth-Bound Patients

By Satish K. Mehta, Ph.D.
Enterprise Advisory Services
NASA Johnson Space Center

Duane L. Pierson, Ph.D.
NASA Johnson Space Center

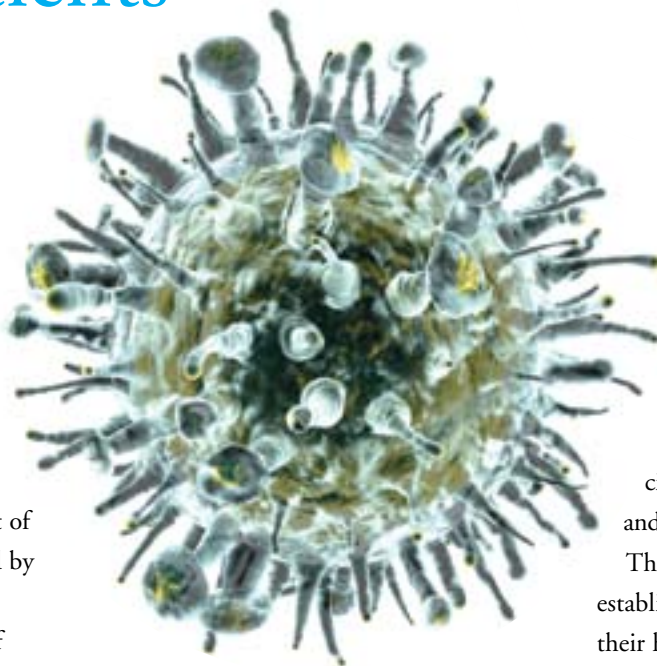
C. Mark Ott, Ph.D.
NASA Johnson Space Center

Spaceflight alters some elements of the human immune system, and while astronauts are among the healthiest of individuals, even they are impacted by this phenomenon.

Innate immunity, an early line of defense against infectious agents, and specific components of cellular immunity, are decreased in astronauts during space shuttle missions of 16 days or less. T-lymphocytes (cellular arm) of the immune system are especially important in combating viral infections.

Astronauts do not experience increased incidence or severity of infectious disease during short-duration spaceflight, but NASA scientists are concerned over just how the immune system will function over long stays in space, as required by exploration missions.

Selecting one or more biomarkers



(indicators) of immunity in healthy individuals is difficult, but the herpes viruses have become valuable tools in early detection of changes in the immune system, based largely on the astronaut studies.

Eight herpes viruses call the human body home, and virtually everyone is infected by one or more of these viruses. They can cause diseases including common “fever blisters” (herpes simplex virus-HSV), infectious mononucleosis (Epstein-Barr virus-EBV), and chicken pox and shingles (varicella zoster virus-VZV). In immunosuppressed indi-

viduals, herpes viruses may cause several types of cancer such as carcinoma, lymphoproliferative disease and others.

These viruses have the ability to establish long-term associations with their human host. For example, after the primary disease (e.g., chicken pox) subsides, VZV migrates up a peripheral nerve and remains inactive (latent) in dorsal root ganglia of nervous tissue located along the length of the spinal cord. This begins a life-long association between a human host and the herpes virus. Then during periods of decreased immunity, VZV “reactivates” in some sensory ganglia, multiplies, migrates down one or two peripheral nerves and initiates the painful skin lesions known as shingles.

According to the Centers for Disease Control and Prevention, one million cases of shingles occur yearly

in the U.S., and 100,000 to 200,000 of these cases develop into a particularly painful and sometimes debilitating condition known as post-herpetic neuralgia, which can last for months or years. The other seven herpes viruses also can exist in an inactive state in different body tissues much like VZV, and similarly they may also reactivate and cause disease during periods of decreased immunity.

The most common cause of decreasing immunity is age, but chronic stress also results in decreased immunity and increases risk of the secondary disease such as VZV-driven shingles. Chemotherapy, organ transplants and infectious diseases such as human immunodeficiency virus (HIV) also result in decreased immunity.

Thus, viral reactivation has been identified as an important *in vivo* indicator of clinically relevant immune changes. In fact, studies of immunocompromised patients indicate that these patients shed EBV in saliva at rates 90-fold higher than found in healthy individuals.

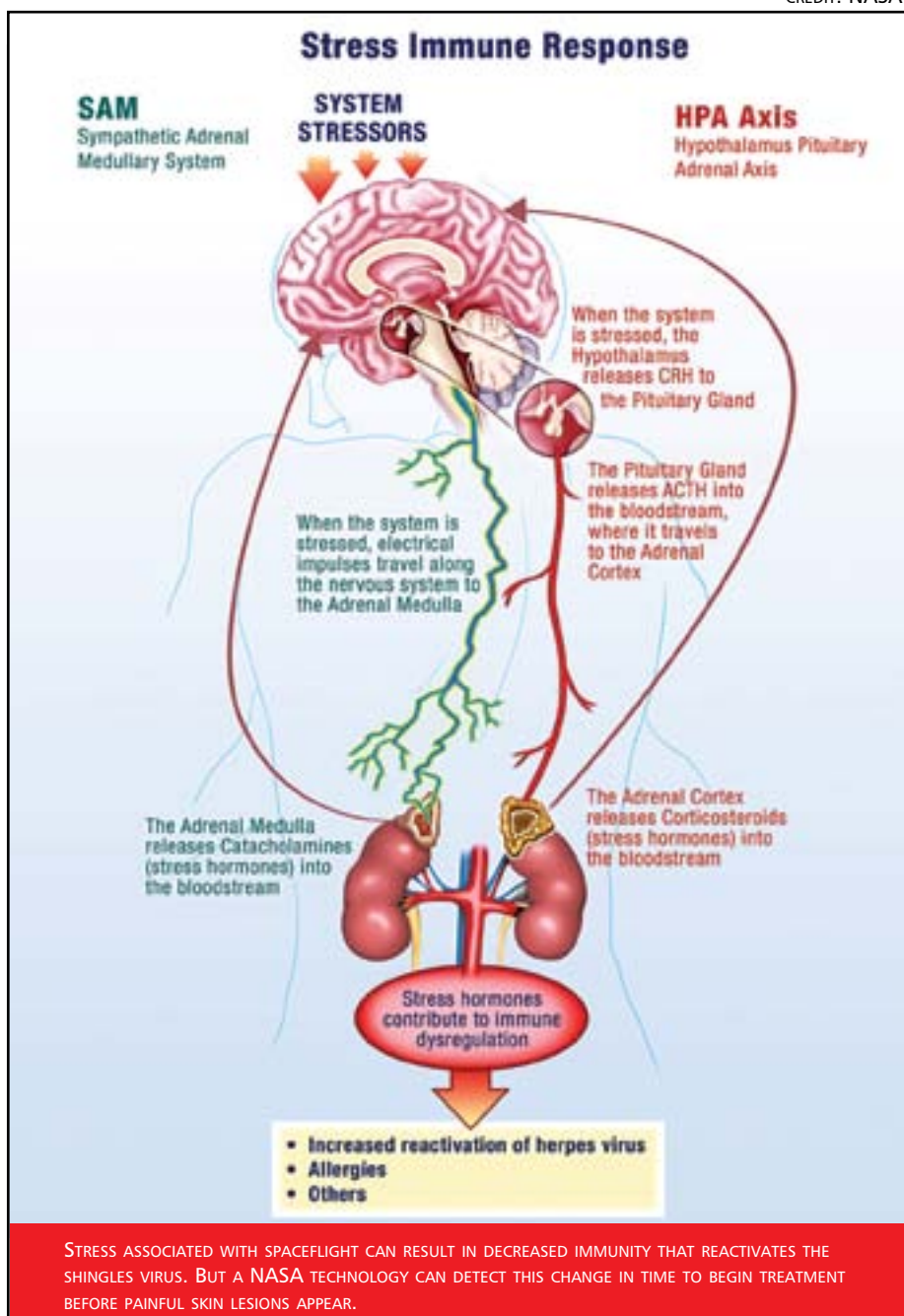
The herpes viruses are already present in astronauts, as they are in at least 95 percent of the general adult population worldwide. So measuring the appearance of herpes viruses in astronaut body fluids serves as a much-needed immune biomarker.

It is widely believed that various stressors associated with spaceflight are responsible for the observed decreased immunity. Researchers at NASA Johnson Space Center found that four human herpes viruses reactivate and appear in body fluids in response to short-term (less

than 16 days) spaceflight. These viruses reactivate and shed at above-normal rates in response to moderately decreased T-lymphocyte immunity in astronauts prior to flight, during flight and immediately after flight.

These stressors act through the hypothalamus-pituitary-adrenal (HPA)

axis and the sympathetic-adrenal medullary (SAM) axis. When responding to stress, the HPA and SAM axes increase the amount of stress hormones, such as cortisol, released from the adrenal glands. The resulting reduction in cellular immunity allows the viruses to emerge from their latent



state into active infectious agents.

The multiplying viruses are released into saliva, urine or blood and can be detected and quantified by a polymerase chain reaction (PCR) assay for each specific virus. The PCR assay detects viral DNA and is very sensitive and highly specific, allowing the user to selectively replicate viral DNA sequences. The finding of VZV in saliva of astronauts was the first report of VZV being reactivated and shed in asymptomatic individuals.

Subsequently, the VZV shed in astronaut saliva was found to be intact and infectious, posing a risk of disease in uninfected individuals.

The PCR technology was the first to demonstrate that EBV reactivation in astronauts was approximately 10-fold higher than reactivation in healthy control subjects. Whereas EBV reactivation is not expected to produce serious effects in astronauts on missions of six months or less, VZV reactivation in astronauts could produce shingles. Reactivation of live, infectious VZV in approximately 50 percent of asymptomatic astronauts was demonstrated to occur during and after spaceflight.

PCR technology also was utilized to study VZV-induced shingles in patients from the general population. In the study, which merged the experience of physicians at the University of Texas Health Science Center in Houston and NASA scientists at Johnson Space Center, salivary VZV was present in each of the 54 shingles patients on the day treatment was initiated. Pain and skin lesions decreased following

antiviral treatment, and levels of VZV decreased as well. The lower levels of VZV copies in shingles patients before treatment overlapped the upper range of VZV levels in astronauts, suggesting a potential risk of shingles from VZV reactivation in space.

This early-detection technology was used to facilitate early diagnosis of shingles in a 21-year-old patient, resulting in early medical intervention. This quick action prevented the formation of skin lesions and reduced the duration of pain associated with acute disease.

In another NASA study, spaceflight PCR technology was utilized to detect VZV in the serum and peripheral blood mononuclear cells of all 25 shingles patients, demonstrating for the first time that viremia (virus in the blood) is a common manifestation of shingles. However, the PCR assay requires large, complex equipment, which is not practical for spaceflight.

To overcome this obstacle in an effort to investigate viral reactivation in crewmembers, NASA developed a rapid method of detection of VZV in body fluids, and a patent application is currently pending for it. The new technology requires a small sample of saliva, which is mixed with specialized reagents that produce a red color only when VZV is present. This technology makes possible early detection, before the appearance of skin lesions. Early detection allows for early administration of antiviral therapy and thus limits nerve damage and prevents overt disease. Rapid intervention is expected to prevent post-herpetic neuralgia. The device is designed for use in doctors'

offices or spacecraft and can be modified easily for use with other viruses in saliva, urine, blood and spinal fluid. The sensitivity and specificity emanates from an antibody-antigen reaction.

In another collaborative study, NASA and University of Colorado Health Science Center (Denver) researchers developed a collection tool for assessment of salivary stress hormones during space shuttle missions. Saliva samples are collected on individual filter paper strips and dried. The dried samples remain stable at room temperature for as long as six months to allow testing once back on Earth. The test measures cortisol and dehydroepiandrosterone (DHEA), two important stress and immune regulatory hormones. The filter paper also can be used for proteins and other molecules of interest in saliva. Booklets of these filter papers now are being used in university and government laboratories for remote saliva collection.

These studies demonstrate the potential value of bringing to the general public a technology that could prevent a painful and debilitating condition in up to one million people each year in the U.S. alone. ■

The authors are in the Habitability and Environmental Factors Division at NASA Johnson Space Center. Satish K. Mehta, Ph.D., is a senior scientist; C. Mark Ott, Ph.D., is a senior microbiologist; and Duane L. Pierson, Ph.D., is the chief microbiologist.

For more information, please contact Dr. Pierson at duane.l.pierson@nasa.gov.

Please mention that you read about it in Technology Innovation.

NASA Contributes to the Understanding of Infectious Diseases

NASA technology has helped make outbreaks of disease predictable through remote sensing data, and microgravity research in space has contributed to what we know today about infectious disease.

Satellites as Mirrors of Earth

Many infectious and chronic diseases are related to environmental conditions. High concentrations of ground-level ozone, particulate matter and/or other atmospheric pollutants can worsen respiratory diseases such as asthma and emphysema. The Centers for Disease Control and Prevention maintains decision support systems for public health that provide vital information on these conditions and allow for the prediction of disease outbreaks. NASA provides remote sensing data to the CDC and the states, enhancing these decision-support systems.

Earth-observing satellites from NASA's Landsat Program have been taking specialized digital photographs of Earth's continents and surrounding coastal regions for over three decades, enabling scientists to study many aspects of our planet and to evaluate the dynamic changes caused by both natural processes and human practices. Valuable information is collected about conditions that are favorable to the spread of diseases like asthma, emphysema, Lyme disease and cholera, and

enabling the prediction of when and where outbreaks may occur.

NASA's Ames Research Center collaborated with the New York Medical College and the Yale School of Medicine to develop remote sensing-based models for mapping Lyme disease transmission risk in the northeastern U.S.

Landsat remote sensing data also provided information related to cholera in Bangladesh.

The Terra and Aqua satellite missions return data on factors like vegetation, forests, flooding, wetlands, soil moisture, surface ultraviolet radiation and surface temperatures. Both Terra and Aqua carry the Moderate-Resolution Imaging Spectroradiometer (MODIS), which contributes information on weather and climate favorable to vectors like ticks and mosquitoes.

New Space Station Opportunities

To gain new insights into how cells fight off infections, NASA scientists conduct research in the unique environment of space. In April 2010 NASA sent some new experiments to the International Space Station (ISS) aboard Space Shuttle Discovery.


One of those experiments, known as the Space Tissue Loss (STL) experiment, or STS-Immune, is led by Cheryl Nickerson, Ph.D., associate professor of life sciences at the Center for Infectious Diseases and Vaccinology in the Biodesign Institute at Arizona State University. STS-Immune is the

first fundamental biology experiment to conduct an in-flight infection of human cells using pathogenic bacteria. It will characterize the effect of microgravity on intestinal cellular responses before and after *Salmonella* infection during space flight.

During previous experiments in space, Dr. Nickerson and her ASU team of scientists discovered that space flight uniquely enhances the virulence and globally alters gene expression patterns of the organism *Salmonella typhimurium*, a major food borne pathogen. Understanding how microgravity alters virulence allows scientists to understand the mechanisms of how this disease works, leading to preventive vaccines that are now in development.

"Only by studying how cells respond to microgravity can we reveal important biological characteristics that are masked by normal gravity when using traditional experimental approaches on Earth," says Dr. Nickerson.

Another experiment just delivered to the ISS by Discovery is Mouse Immunology, which looks at the influences of microgravity on the immune systems of mice. Led by Millie Hughes-Fulford, Ph.D., a former NASA astronaut and professor in the departments of Medicine and Urology at the University of California, San Francisco, the experiment will test whether space flight affects an immune system response to a new infection or re-infection.



NASA Technologies Address the Aging Population

By Victor Schneider, M.D.
NASA Headquarters

Americans can look forward to living into old age, in many cases thanks to new technologies that address the unique needs of the aging population. Many of these technologies have been and continue to be developed by NASA, either directly for the health-related fields or through adaptation and commercialization of innovations originally created to meet the requirements of the space program.

Over the years, NASA research has improved the survival rate of patients in intensive care and coronary care units with the development of medical monitoring and telecommunications technology. Among the Agency's research and development efforts that have led to medical successes are those that have helped devise and test rechargeable batteries for pacemakers; supported the development of an insulin pump to treat diabetes mellitus, developed software for modern magnetic resonance imaging to better identify pathology; and enhanced the ability to

detect early breast cancer lesions.

Innovation and practical biomedical research continue to be important to NASA. The following examples demonstrate how current NASA research results in technologies that have great potential to benefit the aging population.

Stronger Hip Replacement Implants

In 2001, NASA had a need to improve surface enhancement of metallic materials to increase the durability of a turbine engine's metal components. With support from NASA's Small Business Innovation Research (SBIR) program, Lambda Technologies of Cincinnati, Ohio (www.lambdatechs.com), joined with NASA Glenn Research Center to perfect the company's Low Plasticity Burnishing™ (LPB™) method. This technique creates a finite surface finish that imparts a deep layer of compressive residual stress at the surface, increasing finite fatigue life of metallic components by an order of magnitude while doubling endurance limits and retarding existing cracks.

LPB met NASA's needs and went on to further success, gaining wide acceptance in military and commercial aviation. In the biomedical arena, the technique is being used to strengthen implanted total hip prosthesis systems.

It is estimated that more than 300,000 hip replacement surgeries are performed each year in the United States to alleviate pain and improve the function of hips damaged from disease or fracture. Day-to-day activities of a patient can lead to high cycle fatigue

failure in previous hip-replacement devices. However, Lambda's patented LPB process improves high cycle fatigue performance and eliminated the occurrence of fretting-induced fracture in the hip prosthesis by producing beneficial, compressive residual stresses.

Lambda, along with orthopedic implant manufacturer Exactech (www.exac.com) of Gainesville, Fla., began implementation for production LPB processing that led to manufacturing start-up in January 2005. Lambda initiated the first commercial application of LPB to medical implants, and Exactech applied this unique technology to improve the fatigue strength in the neck segments of modular total

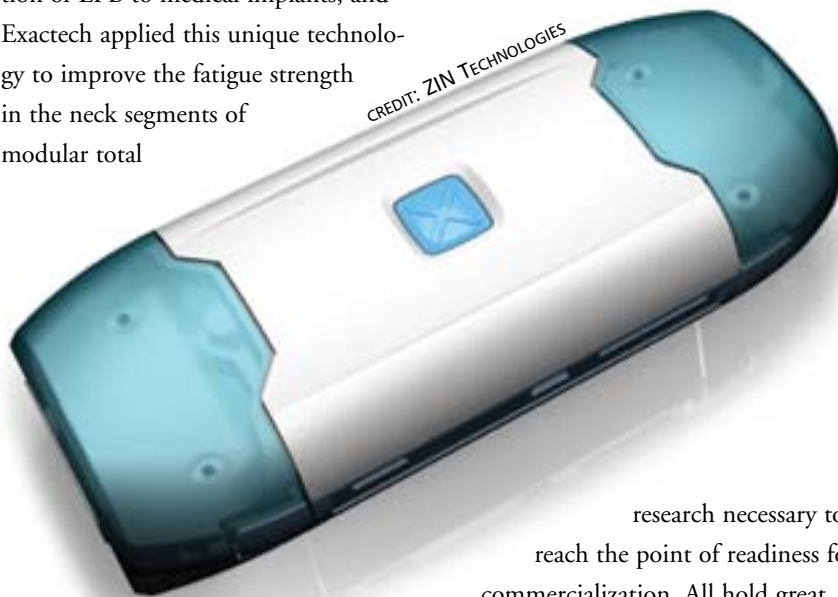
hip prostheses by 40 percent.

In 2009, Lambda's spinoff company, Surface Enhancement Technologies, received an FAA license to use the process to repair and modify aircraft components. The company now has an exclusive partnering agreement with Delta Airlines.

Lambda's CEO and director of research, Paul S. Prev  y, noted that working with NASA soon after the 1996 patent filing was important to getting the word out about the process.

"NASA's support of LPB through its Web site has continued to encourage inquiries from industry, which have led to further commercialization," he says.

While the LPB has already joined the list of commercial medical technologies having received their start at NASA, the following NASA technologies are still undergoing the intensive



research necessary to reach the point of readiness for commercialization. All hold great potential, however, to further transform the practice of medicine, particularly as the population ages, and may someday become as familiar to us as the CAT scan and the MRI are today.

Wireless Health Monitors

Two technologies developed by NASA to monitor astronauts' health

ABOVE: ZIN TECHNOLOGIES AND THE CLEVELAND CLINIC DEVELOPED BIOWATCH TO ADDRESS NASA'S NEED TO IMPROVE BIOSENSOR DATA MANAGEMENT ONBOARD THE SPACE STATION.

have the potential for use on Earth in monitoring patients at home after surgery; those with chronic conditions such as heart disease, arterial disease, hypertension, diabetes, pulmonary disease or sleep apnea; or clinical trial participants.

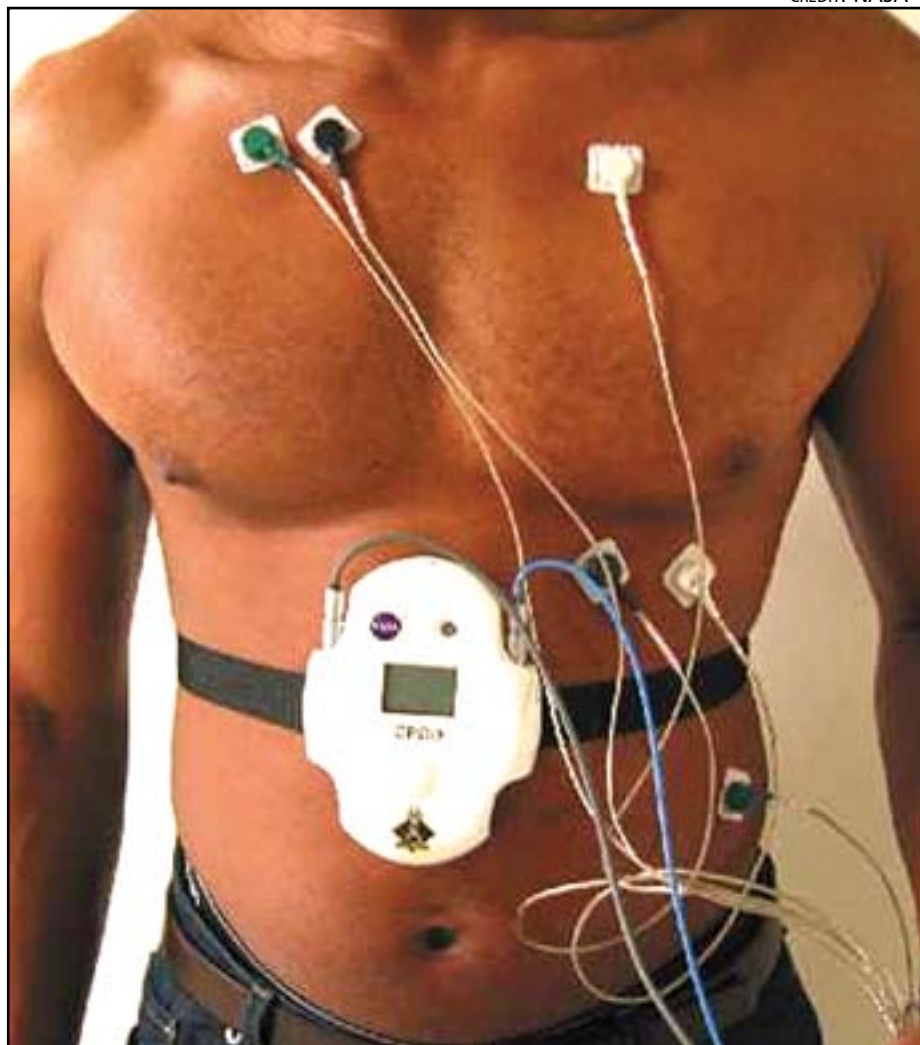
Patient care monitoring is increasingly shifting from anchored in-clinic settings to ambulatory home and even mobile environments. This accelerating shift, which lowers overall costs, is heightening the need to remotely monitor multiple, complex vital signs and other physiologic parameters simultaneously. The need extends to include specific monitoring requirements that often differ between patients and incidents depending upon the applicable disease management or diagnosis protocols and standards of care.

The two monitoring devices, Crew Physiological Observation Device (CPOD) and Biomedical Wireless and Ambulatory Telemetry for Crew Health (BioWATCH) are small and non-invasive, and are being developed to monitor the vital signs of astronauts aboard the International Space Station (ISS).

Both are worn on the body and wirelessly record or transmit information in real time to a physician on Earth. They monitor continuously for up to nine hours while the wearer goes about his or her daily routine.

CPOD is being developed by NASA Ames Research Center in partnership with Stanford University (www.stanford.edu) to keep track of heart rate, blood pressure, body temperature, breathing rate and blood oxygen content.

With Small Business Innovation



CREDIT: NASA

DEVELOPED BY NASA AMES RESEARCH CENTER AND STANFORD UNIVERSITY, THE CREW PHYSIOLOGICAL OBSERVATION DEVICE (CPOD) MONITORS ASTRONAUTS' HEART RATE, BLOOD PRESSURE, BODY TEMPERATURE, BREATHING RATE AND BLOOD OXYGEN CONTENT. THE DEVICE HOLDS PROMISE FOR USE ON EARTH AS WELL, MONITORING PATIENTS AT HOME AFTER SURGERY OR THOSE WITH CHRONIC CONDITIONS.

Research (SBIR) funding from NASA Glenn Research Center, ZIN Technologies (www.ZIN-tech.com) of Cleveland, Ohio, partnered with the Cleveland Clinic (www.clevelandclinic.org) to develop BioWATCH.

This device monitors heart rate, blood pressure, glucose, temperature, joint angles, body weight, planter pressure, electrocardiogram data, blood oxygenation and other data.

ZIN Technology also is developing a commercial version of BioWATCH called vMetrics™, which has a platform technology that integrates with existing health care IT infrastructures supporting current patient electronic medical records standards. vMetrics will transmit data to doctors in real time via cell phone, wireless internet or Bluetooth and have the capability to be configured to monitor various conditions, mak-

ing it ideal for patients receiving home health care. It would eliminate the need for outside labs and technicians and could reduce the cost or need for hospitalizations and visits to the doctor, saving time, money and undue anxiety.

As health care institutions adopt remote monitoring to better manage their outpatient and home health care services, and as home and remote monitoring for disease maintenance and diagnosis are increasingly reimbursable, the ability to implement remote measurement provides more effective heal¹

Decontaminating O Implants

While researching oxidizing effects of atomic oxygen on spacecraft materials, scientists at NASA Glenn realized that it could be beneficial in other applications, including decontaminating surgical implants.

Just as atomic oxygen oxidizes hydrogen, carbon and hydrocarbon polymers on surfaces in space, the gas likewise was found to have the potential to remove bacterial contaminants from surgical implants. Together with DePuy Orthopaedics (www.depuy-orthopaedics.com) of Warsaw, Ind., NASA Glenn developed a method of using atomic oxygen for this purpose.

The surfaces of most orthopedic implants are contaminated with endo-

toxins, non-living chemicals consisting of mostly bacterial cell wall fragments. Standard sterilization practices do not remove endotoxins, which can go on to cause inflammation and pain after implantation, possibly leading to joint loosening and implant failure.

With some several hundred thousand orthopedic devices being implanted each year among Americans aged 70 and above due to hip fracture, the reduction in inflam-

mation through use of atomic oxygen to remove endotoxins could be significant, translating to equally significant cost savings and improvements in quality of life.

Use of atomic oxygen for removal of endotoxins from orthopedic implants is still in the research phase and is not yet in use commercially for this purpose.

Better Blood Glucose Monitoring

Atomic oxygen also was key to NASA's discovery of a faster method of monitoring blood glucose.

Developed by NASA Glenn Research Center in collaboration with Light Pointe Medical (<http://lightpointemedical.com>) of Eden Prairie, Minn., the innovation is an atomic oxygen-based method of producing the active sensor tip on an optical fiber, which is used in a blood glucose monitoring system.

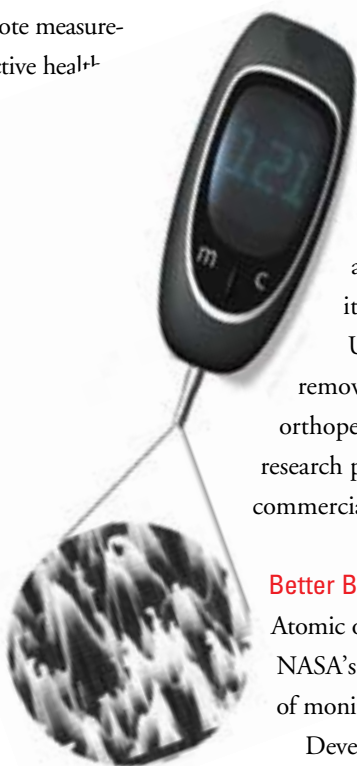
The monitor has undergone proof

of concept and continues to be further developed at Light Pointe Medical.

The system requires much smaller quantities of blood than is required by conventional lance and absorbent strip devices. Use of the fiber sensor likely will promote more frequent use of the monitor, resulting in better control of glucose levels.

Microscopic cones on the tip surface of optical fibers are produced to allow the rapid measurement of blood glucose and other analytes. The texturing provides a separation of red cells from blood plasma, increases the surface area on the fiber tip with less blood volume required, and provides a faster measurement response time. The cones are coated with reagents and chemicals to provide an accurate color change measurement of blood glucose levels.

NASA's contributions to these and many other technologies will continue to improve the lifestyles of Americans as they enter their golden years, as innovations developed for the space program are adapted to meet the health care needs of an aging population. ■



Victor Schneider, M.D., is enterprise scientist/medical research officer in the Exploration Systems Mission Directorate at NASA Headquarters.

For more information about any of the technologies discussed, please contact the Innovative Partnerships Program (IPP) chief at the appropriate NASA Field Center. Contact information is listed in the IPP Network Directory in the back of this magazine.

Please mention that you read about it in Technology Innovation.

ABOVE: ATOMIC OXYGEN IS EMPLOYED IN A NEW TECHNOLOGY THAT MEASURES BLOOD GLUCOSE IN A MANNER THAT IS FASTER THAN THE CURRENT METHOD. CREDIT: LIGHT POINTE MEDICAL



Mitigating Astronauts' Health Risks from Space Radiation

By Francis A. Cucinotta, Ph.D.
NASA Johnson Space Center

One of the unique challenges for NASA is how to protect astronauts from the radiation environment in space. For instance, our sun emits medium- to high-energy protons in what are known as solar storms. The storms vary in size and arise with little warning, and they could expose crewmembers to high doses of radiation when shielding is not present. Also, the stars in our galaxy emit ions that are accelerated by supernova to create highly energetic ions that can burrow deeply into spacecraft structures and tissues.

These resulting galactic cosmic rays (GCR), consisting of high-energy protons and heavy ions such as the nuclei of oxygen, silicon and iron atoms, are the most challenging part of the space

radiation problem. This is because their higher energies make them much more penetrating than protons emitted during solar storms, and prohibitive to shield against because of the enormous mass required even for the best shielding material. More importantly, the biological effects of the GCR are poorly understood with uncertainties in current risk projections prohibitive to NASA's exploration plans.

Life on Earth is protected from space radiation by the Earth's atmosphere and magnetosphere, and astronauts in low Earth orbit (LEO) are partially protected with a dose-rate of about 1/3 of that in deep space. As missions outside LEO are planned, the full burden of daily GCR exposures is unavoidable. NASA must find a solu-

tion to this problem in order to implement plans for planetary exploration.

The basic understanding of space environments and radiation transport shielding materials was investigated by NASA's Johnson Space Center and Langley Research Center in the 1980's and 1990's. The physical characterization of shielding materials and organ doses is now well understood. Other efforts by Johnson Space Center, with the support of NASA Ames Research Center, have developed radiation dosimetry for real-time characterization of the dynamic space environment. However, a large scientific challenge remains in understanding the radiation biology of health risks such as cancer, and degenerative diseases such as arteriosclerosis, cataracts



and Alzheimer's disease that may be increased or advanced to earlier ages by radiation exposure. This understanding is needed for accurate risk assessments related to setting exposure limits and shielding requirements, and for the development of biological countermeasures.

Partnership with DoE

In order to overcome this challenge, NASA has created a unique partnership with the Department of Energy's (DoE) Brookhaven National Laboratory (BNL) (<http://www.bnl.gov/world/>) in Upton, N.Y. (Long Island) through the 2003 creation of the NASA Space Radiation Laboratory (NSRL) (<http://spaceradiation.usra.edu>). Managed by Johnson Space Center, the NSRL uti-

lizes the BNL's large complex of particle accelerator facilities to speed ions to the high energies that occur in space, thus allowing for detailed and controlled experimentation. Along with the capability to accelerate individual ion species from protons to iron that comprise the GCR, the NSRL allows space scientists to investigate mixed radiation fields such as the distribution of energies that occur in the great solar storms, or mixtures of ion types and energies that represent the GCR in deep space or on the Mars surface.

State-of-the art biological laboratories were created at Brookhaven to support the NSRL research program. More than 100 scientists per year from U.S. universities or government laboratories, as supported by NASA

through openly competed research grants, will journey to Brookhaven several times each year to irradiate biological samples such as 2D or 3D human cell culture or transgenic mouse models of human disease. The laboratories allow investigators to utilize similar measurement devices for gene and protein expression, confocal microscopy or tissue pathology that they enjoy in their home institutions. They also have the ability to set up their experimental systems or to fix samples prior to transferring them back to their home institutions for further investigation.

This partnership between NASA and DoE allows a smooth operation in the selection of ion beams and energies, the scheduling of scientists

CREDIT: BROOKHAVEN LAB



THE NASA SPACE RADIATION LABORATORY (NSRL) OPENED IN 2003 AT THE DEPARTMENT OF ENERGY'S BROOKHAVEN LAB TO STUDY THE POSSIBLE RISKS TO HUMANS WHO ARE EXPOSED TO SPACE RADIATION. SHOWN HERE IS THE NSRL BEAM LINE, WHERE BEAMS SIMULATING THE COSMIC RAYS FOUND IN SPACE HELP RESEARCHERS STUDY THESE RADIOBIOLOGICAL EFFECTS.

to optimize 12-hour days of exposure with protons and heavy ions, and travel between holding laboratories at the NSRL and long-term laboratories sponsored by NASA in BNL's medical department. NASA and DoE also partner on joint selection of research proposals from the DoE's Low Dose research program. This collaboration increases the scientific pool utilizing NSRL and an annual Space Radiation Summer School at BNL with a goal of attracting the best students to a career in space radiation research.

The Scientific Challenge

On Earth, we are familiar with X-rays and gamma-rays used in medical treatment or diagnostics, or epidemiology studies of experiences of the atomic-bomb survivors in the Japanese cities of Hiroshima and

Nagasaki. Energetic photons such as X-rays and gamma-rays cause biological damage through the ionization effects of electrons that are produced as photons traverse cells or tissues.

Two attributes make the GCR different from X-rays or gamma-rays: First their large ionization power, which increases with the square of the charge of the nucleus (for example 8^2 , 14^2 and 26^2 for the nuclei of oxygen, silicon and iron, respectively). Their greater ionization power allows GCR to ionize biomolecules in qualitatively distinct ways from X-rays or gamma-rays, creating new types of DNA damage or patterns of damage in cells and tissue. The second difference is the correlation of the damage along the path of the ion. Gamma-rays will produce a random distribution of ionizations in tissues

with a slow exponential decrease in dose with tissue depth. GCR produce a correlated pattern of damage along the ions' trajectory, thereby producing a column of damage cells. These two differences limit the applicability of epidemiology studies of humans exposed on Earth for estimating the risks to astronauts. Instead, a basic science approach is needed to develop risk estimates.

Biological research is often very descriptive. However, to aid NASA, a quantitative approach is needed, such as triplicate experiments with multiple ion beams and mixed radiation fields, in some cases using multiple dose-rates. This obviously is a slow process. Further complicating the matter is the long times after exposure called for in cancer and degenerative risk research, and the limits to how often scientists

CREDIT: BROOKHAVEN LAB

can journey back to NSRL to repeat, iterate and evolve their experiments. However, after seven years of operations, researchers are publishing papers at a rapid pace, discussing research performed at NSRL. More than 60 peer-reviewed articles appeared in scientific journals in 2009.

The immediate goal of the NSRL research is to reduce the uncertainties in risk projections that are a large safety concern and that inhibit mission planning. Uncertainties are a two-sided coin whereby new knowledge can lead either to higher or lower risks along with uncertainty reduction. On the positive side, research is showing the risks of leukemia from GCR is over-estimated in the current radiation protection model followed by NASA. The model originates from the U.S. National Council on Radiation Protection and Measurements (NCRP), a body chartered by Congress to guide federal agencies on radiation protection. On the negative side are results that suggest the risks of solid cancer may be higher than has been estimated, and the risks of degenerative diseases once thought to be less than likely now appear to be very likely for a Mars mission or other long-term space missions.

Only through continued experimentation with more and more sophisticated biological models of human disease will the true answer to the magnitude of the space radiation risk be solved, and approaches to mitigate the risks identified. Key results to date are allowing NASA to focus critical resources on the



THE NASA SPACE RADIATION LABORATORY (NSRL) EMPLOYS BEAMS OF HEAVY IONS EXTRACTED FROM BROOKHAVEN'S BOOSTER ACCELERATOR, THE ONLY FACILITY IN AMERICA FOR RADIOBIOLOGY STUDIES. NSRL ALSO FEATURES ITS OWN BEAM LINE DEDICATED TO RADIOBIOLOGY RESEARCH, AS WELL AS STATE-OF-THE-ART SPECIMEN-PREPARATION AREAS.

health risks with higher magnitudes as the main target for biological countermeasure development and will allow more precise estimates of the benefits of shielding materials and crew attributes such as age and gender.

Space radiation research has far-reaching applications on Earth as well. NASA's approaches to the radiation protection of astronauts has benefited radiation protection policies and practices on Earth including in the medical uses of radiation in areas such as computed tomography (CT) and workers at nuclear reactors in the U.S. Studies of the distinct challenges from space radiation and new approaches to countermeasures are enhancing today's research into cancer and the effects of aging. The research also has impacted the development of new cancer therapies that employ high-energy proton

and carbon beams to kill cancer cells while producing less damage in the surrounding normal tissues, representing improvements over X-rays.

The pace of NSRL results is accelerating, leading to a growing enthusiasm that in the new decade this innovative approach using inter-Agency cooperation, one-of-a-kind accelerator technologies, and basic science to understand a major challenge to space exploration will be successful. ■

Francis A. Cucinotta, Ph.D., is chief scientist in the NASA Space Radiation Program at Johnson Space Center

For more information, contact Dr. Cucinotta at francis.a.cucinotta@nasa.gov.

Please mention that you read about it in Technology Innovation.

Space Technology to Maintain Cardiac Health

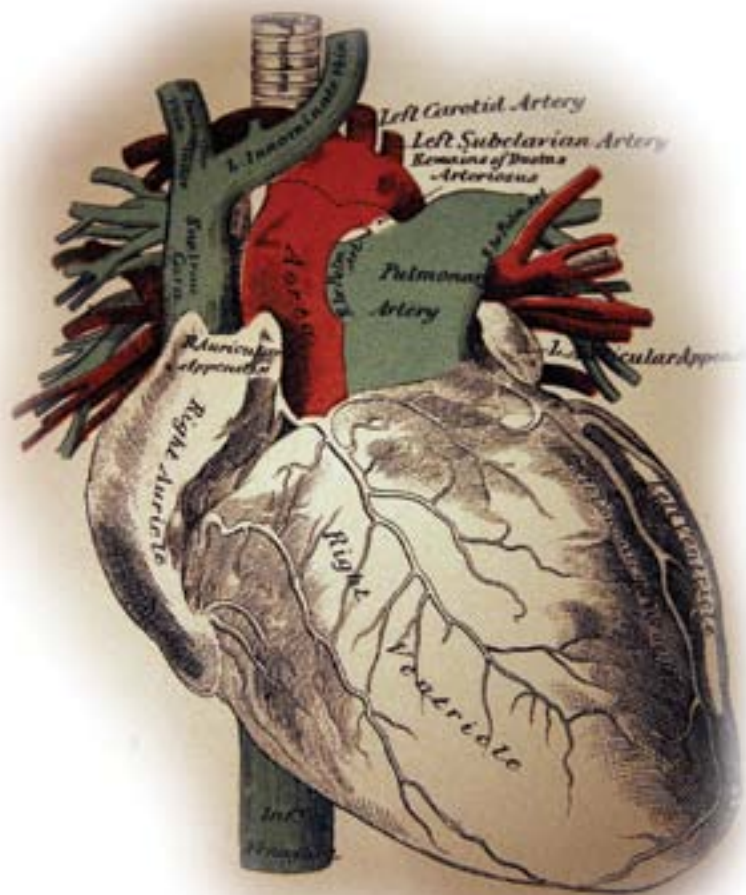
By Douglas Hamilton, M.D., Ph.D.
Wyle Integrated Science
and Engineering

Long- and short-term exposure to microgravity significantly alters the cardiovascular system. Furthermore, astronauts may have undetected cardiac disease, which may be exacerbated by the cardiovascular system's adaptive responses to microgravity.

The U.S. and the Russian space programs have implemented extensive research programs to understand the alterations in cardiovascular physiology that are induced by exposure to microgravity. These changes in physiology may eventually manifest themselves in the form of impaired cardiovascular performance such as the inability to maintain blood pressure after standing upright, decreased exercise capacity postflight or heart rhythm disturbances on-orbit.

The space medicine physician needs to understand these important physiological effects on the human cardiovascular system so that he or she can place them within the operational context of a space mission. In doing so, all phases of a space mission must be considered, beginning with crew selection and proceeding through launch, on-orbit activities, reentry and post-flight recovery.

The primary role of space medicine physicians is to prevent the occurrence



of cardiovascular illness or impaired performance in spaceflight, and to rehabilitate or treat impaired cardiovascular function in a manner that minimizes mission impact while maximizing crew health and performance.

These roles are very similar to what physicians practice on Earth but get complicated by the challenges of delivering medical care in space. NASA uses technology to solve many complex

issues with regard to engineering and fabrication of existing and future space vehicles. In some cases these technologies have also found their way into the terrestrial medical arena, where they can enhance the health and performance of humans on Earth.

Material Science Advances

Heart failure occurs in humans when the heart is unable to pump enough

blood to meet the body's oxygen needs. It is a chronic and progressive disability that affects more than six million Americans.

Cardiac resynchronization therapy, or CRT, helps coordinate the contraction of the heart's chambers and improve the heart's ability to deliver blood flow to the body. A CRT device differs from a pacemaker, which normalizes a too-slow heart rhythm.

The size of a stopwatch, a CRT device is implanted into the chest and connected to the heart by a special wire. Electrical impulses generated by the CRT resynchronize heartbeats and improve blood flow.

A NASA technology that was developed for an aerospace high-speed research program is now part of a CRT system for heart failure patients. NASA's Langley Research Center in Hampton, Va., created an advanced aerospace resin, named Langley Research Center's Soluble Imide, or LaRC-SI. Rob Bryant, Ph.D., is a NASA Langley senior researcher and inventor of the material. It is highly flexible, resistant to chemicals and withstands extreme hot and cold temperatures. This "super plastic" was determined to be biologically inert, making it suitable for medical use, including implantable devices. One of the advantages of this material is that it lends itself to a variety of diverse applications, from mechanical parts and composites, to electrical insulation and adhesive bonding. NASA has licensed this patented insulation technology to Medtronic Inc. (www.medtronic.com), a Minneapolis-

based medical technology company. Medtronic used the material to insulate its Attain Ability® left-heart lead, which has been approved by the U.S. Food and Drug Administration.

This NASA insulation material makes possible the compact and flexible design of Medtronic's CRT lead,

the Attain Ability lead 96.4 percent of the time.

Even though these CRT technologies will most likely not be used on active astronauts, many space medicine physicians also practice medicine in local clinics where these advances change the lives of their Earth-bound patients.



CREDIT: NASA

INVENTOR ROB BRYANT, PH.D., OF NASA LANGLEY RESEARCH CENTER INSPECTS LARC-SI INSULATION ON LEAD WIRES FOR CARDIAC RESYNCHRONIZATION THERAPY DEVICES (CRT).

one of the thinnest left-heart leads currently available. Placing any lead in the heart is widely recognized by physicians as the most challenging aspect of implanting CRT devices. The narrow Attain Ability left-heart design allows physicians to choose among different sites on the heart to deliver optimal therapy. The lead is delivered by an inner catheter, a feature that helps physicians place the lead directly in difficult-to-reach areas of the heart. Clinical studies in the U.S. and Canada show that physicians were successful in placing

Computational Science Advances

NASA computer scientists made improvements to a battery-operated heart pump with the help of a supercomputer that normally models the flow of fuel through rockets.

At the NASA Advanced Supercomputing Applications Branch, located at Ames Research Center in Moffett Field, Calif., experts analyzed blood flow through the DeBakey miniature heart assist pump, also known as a ventricular assist device (VAD). The DeBakey VAD™, a one-inch by three-inch implantable

CREDIT: MICROMEDCV.COM



TO ANALYZE BLOOD FLOW THROUGH THE NASA/DeBAKEY MINIATURE HEART ASSIST PUMP, NASA COMPUTER EXPERTS USED A SUPERCOMPUTER THAT NORMALLY MODELS THE FLOW OF FUEL THROUGH ROCKETS. THE DEVICE HAS EXTENDED THE LIVES OF MORE THAN 440 PEOPLE SINCE 1998.

axial rotary heart pump manufactured by MicroMed Technology Inc., is a bridge to transplant in patients with end-stage congestive heart failure, as they wait for a donor heart. It is based in part on technology used in space shuttle fuel and oxidizer pumps.

The VAD blade normally spins as fast as 10,000 rpm. The speed of fluid flow through a rocket engine is faster than blood flow, but nonetheless very similar in many ways.

During the simulations, NASA computer scientists addressed the two major problems identified by the VAD engineers during the device's development:

- Friction led to damaged blood cells because the device created high shear flows through pump parts, which can exacerbate an already failing heart.
- Stagnant regions in the pump caused blood clotting, a major problem with ventricular assist devices, which can lead to stroke and other organ failure.

Using supercomputer simulations, NASA computer scientists were able to reduce red blood cell damage and to reduce the stagnant areas and therefore clot formation. Clinical trials in Europe permitted the first patient, a 56-year-old man, to receive the DeBakey VAD™ in November 1998, in Berlin, Germany. The pump functioned normally and to its design specifications. Since then, there have been more than 440 implants worldwide, and the device is FDA approved in all 50 states and CE approved in Europe. It has been implanted for periods of up to 986 days in individual patients.

Although not common, MicroMed reports that there have been four instances of adults supported by the VAD who recovered to the point that the pump was no longer needed.

The HeartAssist 5™ is the latest generation of the DeBakey VAD, and it is FDA-approved for pediatric use.

The VAD represents the success-

ful integration of three groups: the medical team led by Michael DeBakey, M.D., and George Noon, M.D., of the Baylor College of Medicine, systems engineers at Johnson Space Center and the Ames computational team.

Using Telemedicine to Image Hearts

Advanced Diagnostic Ultrasound in Microgravity (ADUM) clinical investigators, working with NASA flight controllers at the Johnson and Marshall space centers, conducted a prospective trial of standard clinical cardiac ultrasound imaging in six long-duration crewmembers on the International Space Station. Each crewmember operator had only two hours preflight training, and 60-minute in-flight sessions were conducted in space. Expert assistance was used with ultrasound video downlink and two-way voice communication.

The investigation team concluded that no consistent effects of long-duration spaceflight could be detected in any of the 36 echocardiographic measurements taken. This finding is reassuring to the space medicine physician since it has been the opinion of the majority of the research community that space causes very serious maladies in the cardiovascular system. (See other applications of ADUM on page 28.)

Cardiac Arrhythmias and Atrophy in Low-Risk Populations

Cardiac arrhythmias have been reported during several spaceflight missions including Apollo, Mir and Skylab. Recent reports suggest that long-duration spaceflight may change the elec-

trocardiographic (ECG) waveforms, potentially increasing the risk of heart rhythm disturbances. However, very few systematic studies of ECG waveform changes have been performed during spaceflight or its most commonly utilized ground-based analog, head-down bed rest.

Johnson Space Center, along with the University of Texas Medical Branch, Galveston (www.utmb.edu), and the University of Ljubljana (www.uni-lj.si/en), Slovenia, are perfecting a potentially new ECG analysis technique performed during spaceflight to identify astronauts who may be susceptible to serious heart rhythm disturbances during space missions.

The risk of serious arrhythmias also is being currently researched on-orbit by researchers from the University of Texas Southwestern Medical Center, Dallas, and the University of Texas, Houston, using high-fidelity ECG recordings of astronauts for 24 hours in space and during their exercise sessions. The techniques created by the ADUM echocardiographic team are being used by this team to make even more precise measurements of the cardiovascular system to identify any concerns that NASA space medicine physicians need to address for exploration class missions. This study is the most comprehensive cardiovascular research project ever conducted in space and should detect even minor cardiovascular changes in astronauts while they are in space, when they are well nourished and exercising regularly.

Image-processing Technology

NASA has been sending spacecraft throughout the solar system for decades, and many of these craft use advanced cameras to create images of our universe and then transmit these pictures back to laboratories on Earth. NASA's Jet Propulsion Laboratory (JPL) Image Processing Laboratory, founded in 1966 to receive and make sense of spacecraft imagery, invented VICAR (Video Image Communication and Retrieval) software that has laid the groundwork for understanding images of all kinds.

JPL investigators partnered with scientists from the University of Southern California (www.usc.edu) to apply VICAR to ultrasound imagery, which was already digitally formatted. The new approach proved successful for assessing plaque buildup and arterial wall thickness, which studies have shown are predictors of heart disease and stroke.

The team then collaborated with a new entrepreneurial company, Medical Technologies International Inc. (MTI) (www.i-mti.com), based in Palm Desert, Calif., which licensed 14 research institutions around the world for pre-U.S. Food and Drug Administration clearance and research-only use of the analysis software. MTI incorporated feedback from these groups into a new clinical software version. It patented these developments and then submitted the technology to a rigorous review process at the FDA, which cleared the device for public use.

The patented software is being used in the company's ArterioVision™, a non-invasive, no-radiation carotid

intima-media thickness test that uses ultrasound image analysis software to identify atherosclerosis, a buildup of cholesterol and fatty substances in the arteries, combined with arterial hardening, both of which increase the risk for heart attack and stroke. This new technology is being used by physicians nationwide and at the space medicine clinic at NASA Johnson Space Center in Houston to help detect and treat cardiovascular disease in the astronaut corps. MTI estimates that ArterioVision has been used in at least 100,000 exams with the number growing rapidly.

In conclusion, the advances in space technology have brought about major breakthroughs in enhancing patient care and astronaut performance through the prevention, detection or treatment of cardiac disease. Although many of these technologies were born out of the necessity to solve non-medical problems, they stand as testament to the fact that sometimes even directed research for a focused space problem can also provide significant medical benefits. ■

NASA is seeking partners on a technology to treat atherosclerosis. Please see page 50 for information.

Douglas Hamilton, M.D., Ph.D., is a NASA flight surgeon and an aerospace engineer with Wyle Integrated Science and Engineering, the prime contractor for the NASA Johnson Space Center Bioastronautics Program.

For more information contact Dr. Hamilton at dhamilton@wylehou.com

Please mention that you read about it in Technology Innovation.

Advanced Ultrasound For the Space Program and On Earth

CREDIT: NASA

By Scott A. Dulchavsky, M.D.
Henry Ford Hospital and

Kathleen Garcia,
Douglas R. Hamilton, M.D., Ph.D.
Shannon Melton and
Ashot E. Sargsyan, M.D.
Wyle Integrated Science and Engineering



ISS EXPEDITION 10 NASA SCIENCE OFFICER LEROY CHIAO AND COL. SALIZHAN S. SHARIPOV ARE SHOWN DURING A DEMONSTRATION OF ULTRASOUND TECHNIQUES APPLICABLE IN EYE TRAUMA EVALUATION IN SPACEFLIGHT. DIAGNOSES ARE MADE BY GROUND-BASED PHYSICIANS USING IMAGES FROM SPACE.

A patient's location at the time of a medical crisis often determines their amount of pain and suffering, and even their chances of survival. As a rule, ease of access to medical care decreases as the distance from a developed metropolitan area increases. Providing medical care for people in remote communities, at research outposts such as Antarctic stations, and on isolated crews such as the International Space Station (ISS) is particularly challenging. Medical care at these remote locations is usually performed by minimally trained medical personnel, and a physician is sometimes available only through phone or internet links, if at all. The ability to quickly diagnose an illness or injury and initiate treatment improves the outcome for the patient and reduces the consequences for the rest of the mission. The ability to make an accurate diagnosis in remote areas reduces

the impact of the incident, and the chances of an expensive and potentially dangerous and possibly unnecessary evacuation.

Ultrasound imaging is among the fastest, safest and most universal diagnostic methods ever invented. It provides much of the information that can be obtained by expensive technologies such as X-ray, computed tomography or magnetic resonance imagery and it is the only method to produce a real-time (live) image that can be interpreted and/or transmitted at the same time. In the right hands, ultrasound instantly answers many clinical questions, shortening the assessment time

and improving outcome.

The NASA Advanced Diagnostic Ultrasound in Microgravity (ADUM) research team, based at NASA Johnson Space Center, tests novel uses of ultrasound in large medical centers and laboratory conditions, and then adapts them for use in space flight, including training and guidance methods for non-medical operators. The ADUM team is comprised of individuals with unique clinical, scientific, engineering, and teaching expertise, as well as direct experience in a multitude of telemedicine projects and programs. A substantial part of the team's experience comes from using the ISS as a sci-

ence platform for ADUM experiments and a number of subsequent research initiatives sponsored by NASA and the National Space Biomedical Research Institute (NSBRI). (See NSBRI article on page 38.)

Earth-Based Testing: Expanded Uses for Ultrasound

Ultrasound is routinely used to obtain diagnostic information about pregnancy and various abdominal and vascular conditions such as gallbladder disease or blood clots in the veins. We have examined the use of ultrasound in additional conditions including collapsed lung, broken bones, injuries to the eyes or head, and infections in the teeth or sinus cavities. A series of ground studies was conducted at a busy Level 1 trauma center in Detroit, Mich., and Calgary, Alberta, Canada.

Patients who have had chest injuries are at risk of a collapsed lung (pneumothorax), which is usually diagnosed with a chest X-ray. In our laboratories and then in a large clinical trial, the ADUM team developed a simple lung ultrasound technique that can be used to diagnose a pneumothorax with higher accuracy than chest X-ray. This new technique is now standard in many hospitals and trauma centers around the world. Using parabolic flight as an analog to microgravity, the ultrasound hardware, astronaut training, and remote guidance procedures were validated for use on the ISS as a potential capability for the medical support of future space missions.

ADUM investigators developed

“cue cards” to rapidly guide non-expert users to perform ultrasound examinations on patients with extremity injury and found that broken bones can be diagnosed with more than 90 percent accuracy after just minutes of training. Ultrasound also can be used to determine if muscles, joints or tendons are injured. Importantly, it provides a convenient way to look at muscles and joints as they move, which is an advantage over X-ray or other techniques that only provide still images of the body.

There is a concern of injuries to the eyes in astronauts due to objects floating in the spacecraft and, more recently, the effect of prolonged exposure to microgravity on vision. Ultrasound can be used to determine if there are foreign particles in the eye and to identify other conditions that could affect eyesight during space travel. Ocular ultrasound also can provide important information about the condition of the brain in head-injured patients. Those with brain swelling can be identified by using ultrasound to measure the size of the nerve in the back of the eye.

Rapid Training for Non-Expert Operators

During an ultrasound examination, a probe is placed on the patient’s body to transmit and receive sound waves to produce a moving image. The technique depends on proper placement and movements of the probe to obtain the best images, and it generally requires hundreds of hours of practice. The ADUM investigators found that it is possible to use non-medical operators

to obtain good quality data if the right clinical questions are asked, and if the operator is given the right amount and type of information and direction from a remotely located expert.

The ADUM team developed a bilingual (English and Russian) computer-based On-Board Proficiency Enhancement (OPE) e-learning tool, which consists of a stepwise program for performing targeted ultrasound examinations after only a short “hands-on” training program before flight. The OPE program includes modules that review equipment set up, basic and advanced ultrasound principles, anatomy, remote guidance principles, and exam-specific suggestions with a reference collection of “target” images. Companion cue cards, which show where to apply the probe to obtain the correct image, were developed for all of the ultrasound examination sets. This training regimen can be completed in two or three hours and includes 30-minute refresher modules to be completed just before an examination.

The key concept developed by the ADUM team is the methodology for “Remote Expert Guidance” of ultrasound examinations, which links a remote expert with the on-site operator in a virtual common working environment. The ultrasound machine video output is transmitted to the remote expert via a satellite or internet connection, and the operator is guided to obtain the ultrasound images via voice commands. This technique has dramatically reduced training requirements (often down to minutes) while

preserving the quality of the ultrasound examinations.

Ultrasound on the ISS

Ultrasound examinations in space have been performed previously by American and Russian astronauts. However, these exams were severely limited by the large amount of time and complex astronaut training required preflight in order to get reasonable data in-flight without assistance from the ground.

Initial trials of the new paradigm, using ultrasound to capture images of the heart and abdomen, led the way to a large series of ADUM experiments on the ISS, sponsored by NASA and the NSBRI. The ADUM investigators stressed the importance of minimal preflight training of astronaut and cosmonaut crewmembers, computer-based refresher e-learning before imaging sessions, and complex ultrasound examinations on the ISS with remote expert guidance.

The *Columbia* shuttle disaster complicated research efforts on the ISS due to limitations in crew time and challenges with launching equipment and supplies. The ADUM experiment team functioned on an accelerated timeline to accomplish scientific objectives without the ability to send any experimental supplies to the ISS. Accordingly, NASA and ADUM engineers broke down the computer-based OPE educational program into smaller "packets" to allow it to be digitally uplinked and assembled on an ISS laptop. NASA also helped the ADUM team accelerate the preliminary ground

experiments, training and software design and to begin the on-orbit activities two years ahead of schedule. This permitted high-quality medical science to be performed on the ISS while the shuttle fleet was grounded.

Crewmembers first performed diagnostic quality cardiac, vascular and thoracic ultrasound examinations on the ISS. Then other astronauts were rapidly trained to expand the capabilities to perform examinations of the heart, lungs, blood vessels and abdomen with a special emphasis on musculoskeletal ultrasound. The crewmembers performed bone ultrasound examinations every month to monitor changes in the bones from a long period without gravity. They submitted a portion of their results electronically from the ISS, which resulted in the first-ever publication submitted from space. Commander Mike Fincke recently commented that "the ADUM training and OPE refresher course is excellent and should be expanded on future flights. This method could be used in medical emergencies on the ISS to guide crewmembers."

The ADUM team then worked with astronauts to perform additional ultrasound examinations on the ISS including teeth, sinus and eyes. Crewmembers could look at changes in the eye and measure the pupil's response to light using this newly developed technique. Their findings were published from orbit as the lead article in the *Journal of Trauma*.

Finally a full examination of the heart was performed without direct video capabilities, using only voice

guidance and relying on pattern recognition developed in the experiment.

More than 100 hours of ultrasound examinations were conducted with long-duration ISS crewmembers, providing a "head-to-toe" assessment of changes in the body associated with space flight. As of the end of 2009, the techniques and solutions developed by the team were officially accepted for medical support of the ISS crews, as well as for conducting experiments in space physiology and clinical space medicine research.

Ultrasound Application Experience

ADUM investigators modified the training methods and remote guidance techniques developed for the space station to extend medical care capabilities on Earth. Non-physician athletic trainers for the Detroit Red Wings hockey team and the Detroit Tigers baseball team were taught advanced ultrasound skills to help with injured athletes. A portable ultrasound device was installed in the locker room of the athletic stadiums and athlete-specific cue cards were developed for common sports injuries. Tele-ultrasound connections were established over the internet between the sporting arenas and Henry Ford Hospital in Detroit, Mich., to allow remote guidance capabilities.

Initial experiences with the hockey and baseball teams showed that the athletic trainers could perform complex muscle, bone and joint ultrasound examinations rapidly and with high diagnostic accuracy, allowing point-of-care diagnosis of athletic injury. Some ADUM investigators have extended

these capabilities to the United States Olympic Training Facilities and have supported the Torino, Beijing and Vancouver games with hundreds of point-of-care ultrasound examinations in athletes with suspected injuries.

The ADUM team has extended the concept to remote environments such as Mt. Everest and the Arctic Circle. The team designed a self-contained system that includes a portable ultrasound device, solar power, satellite

American College of Surgeons to teach ultrasound to the surgeons of the future.

Future Plans

The ADUM team currently is developing a simple, whole-body ultrasound education catalog that can be used to teach non-expert operators to diagnose a wide variety of conditions. An integrated remote medical care device is being created to combine computer education, ultrasound-based diagnosis

guidance). These methods of focused ultrasound have been used successfully on the ISS and in a number of applications on the ground.

Ultrasound is one of the most adaptable diagnostic imaging modalities, which can be used for many medical and surgical conditions. Advances in portability and affordability, coupled with enhanced training programs and tele-ultrasound, can provide powerful diagnostic capabilities anywhere on and off the planet.

The unique requirements of the future space programs will likely require novel strategies to help diagnose and treat illness in space missions outside the lower Earth orbit.

Together with its partners, the ADUM team will work to create new knowledge and capabilities to benefit human health on Earth and in the most daring exploration settings of the future. ■

The just-in-time ultrasound educational programs developed for use in space ... also are appropriate for training health care personnel

phone connectivity and a laptop computer containing educational programs. An untrained mountaineer was able to perform a complete lung ultrasound scan at Advanced Base Camp on Mt. Everest using cue cards and remote guidance. The novice operator was able to send high-quality ultrasound images to the remote expert to diagnose a fellow climber with fluid in the lungs secondary to high altitude.

A similar remote ultrasound system was used at Resolute Bay in the Canadian Arctic Circle to enable non-expert operators to perform targeted scans of almost every organ system.

The just-in-time ultrasound educational programs developed for use in space and for remote locations also are appropriate for training health care personnel. A training program was developed for Wayne State University School of Medicine, and is now used by the

tics and communication capabilities with remote experts to extend high-quality medical care capabilities to remote, rural and underserved regions on the Earth.

The real-time nature of ultrasound imaging and the ability to easily transmit the images to allow remote expert guidance make ultrasound applications especially attractive for remote use. ADUM investigators are studying the possibility of using ultrasound for effectively answering primary clinical diagnostic questions in unconventional settings where ultrasound is the only (or the first available) source of imaging, and where on-site expertise is limited. They have developed and extensively used multimedia e-learning software, which makes a winning combination with real-time mentoring of the distant on-site operator (remote expert

Scott Dulchavsky, M.D., is chair of surgery at Henry Ford Hospital in Detroit, Mich., and the lead investigator in the ADUM project. Kathleen Garcia, Douglas Hamilton, M.D., Ph.D., Shannon Melton and Ashot Sargsyan, M.D., are with Wyle Integrated Science and Engineering and are co-investigators in the ADUM project. Wyle is the prime contractor for the NASA Johnson Space Center Bioastronautics contract, providing medical operations, ground and flight research, space flight hardware development and fabrication, science and mission integration.

For more information please contact Dr. Hamilton at dhilton@wylehou.com.

Please mention that you read about it in Technology Innovation.

Behavioral Health and Performance Tools to Reduce Astronauts' Risks

By James Cartreine, Ph.D.
Harvard University

David Dinges, Ph.D.
University of Pennsylvania

Lauren Leveton, Ph.D.
NASA Johnson Space Center

Raphael Rose, Ph.D.
University of California, Los Angeles

Gary Strangman, Ph.D.
Harvard University

NASA currently flies six-person crews aboard the International Space Station (ISS), with some crewmembers sojourning for as long as six months in the enclosed, confined vehicle built for the microgravity environment.

But with the coming of missions to other destinations, astronauts may leave the relative comfort of low-Earth orbit and travel far greater distances for far greater durations. For example, missions to Mars will be far more autonomous and may involve 10-12 months of travel time in a microgravity environment, both to and from the planet, with stays on the martian surface lasting anywhere

from days to months.

Such missions are outside of NASA's current experience base, and it is widely recognized that there will be many challenges for ensuring the health and safety of crews that embark on such missions.

The potential risks to astronauts' behavioral health and performance posed by lengthy, confining missions may be as critical as many other hazards they face, or even more so.

What is tolerable psychologically for individuals and crews living in space for six months may not hold true for missions that span a year, or even nine months. Stressors that can affect a crewmember's performance, health or safety can arise from many different sources at any time, or be cumulative in nature: environmental factors (noise, temperature, radiation and contaminants); psychosocial factors (poor communication, separation, interpersonal conflict); and mission/operational factors (work overload, scheduling). Even food (its variety, freshness, palatability and even meal-time sharing) or exercise can become stressors for an individual crewmember over time.

Addressing the Risks

NASA's Behavioral Health and Performance (BHP) Element is one of six elements within the Agency's Human Research Program (HRP) conducting research and developing technologies to ensure safe space travel. BHP's goal is to identify, characterize and prevent and/or mitigate behavioral health and performance risks associated with space travel, exploration and return to terrestrial life. To accomplish this, BHP implements a focused research strategy to address the following three human system risks:

- Risk of behavioral and psychiatric conditions
- Risk of performance decrements due to inadequate cooperation, coordination, communication and psychosocial adaptation within a team
- Risk of performance errors due to sleep loss, fatigue, circadian desynchronization and work overload

BHP research addresses gaps in knowledge and technology — knowledge gaps to accurately assess, characterize and quantify risk likelihood and consequence for mission scenarios; and technology gaps to develop countermea-

CREDIT: NASA

asures, monitoring tools and treatment protocols to prevent, mitigate or treat adverse outcomes for the BHP risks.

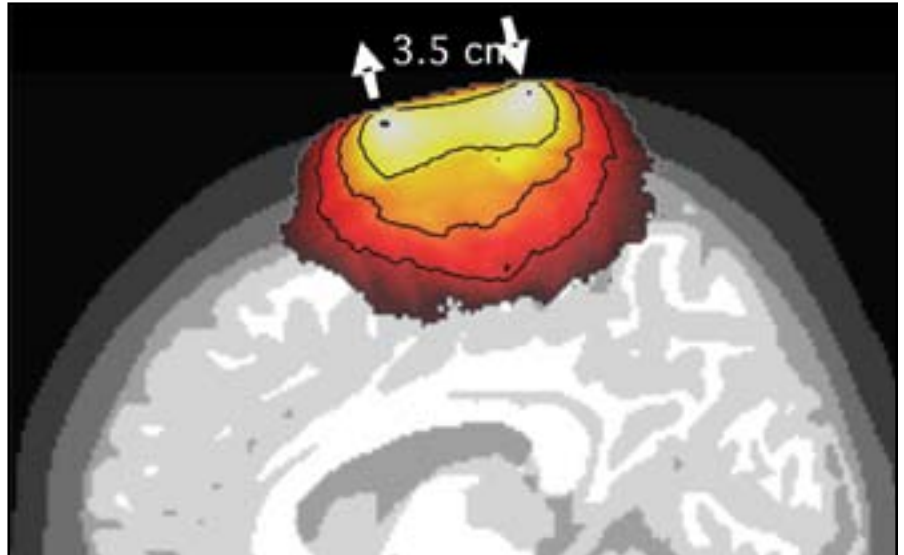
In 1997, HRP entered into a unique partnership with the National Space Biomedical Research Institute (NSBRI) (www.nsbri.org) (see article on page 38) to develop biomedical countermeasures for physiological and psychological risks associated with long-duration spaceflight. Today, many of the concepts and hypotheses that were tested in the laboratories of this consortium of academic institutions have matured to readiness levels that allow their transition to ground-based space analogs such as the NASA Extreme Environment for Mission Operations (NEEMO) for testing, or to spaceflight for final verification and validation.

Highlights of several BHP projects follow.

Neuroimaging for Brain Function

While crew health and performance depend on optimal brain function, many aspects of the spaceflight environment can adversely affect the brain and nervous system. Concerns include space radiation, environmental toxins, elevated carbon dioxide levels, temperature extremes, nutritional effects, sleep deprivation and chronic stress.

Physiological brain monitoring is not part of routine medical care for astronauts, due to an absence of practical neuromonitoring methods. The standard clinical brain imaging methods—computed tomography (CT), magnetic resonance imaging (MRI) and positron



NEAR-INFRARED NEUROIMAGING (NIN) TECHNIQUES HAVE SPATIAL SENSITIVITY PROFILES THAT ALLOW SAMPLING OF SUPERFICIAL BRAIN STRUCTURES. IN OUTPATIENT SETTINGS ON EARTH NINSCAN DEVICES COULD HELP TO IDENTIFY NEURAL MARKERS OF DISEASE, DISEASE SEVERITY OR TREATMENT EFFICACY. HERE IS SHOWN THE SENSITIVITY PROFILE FROM A SINGLE NIN LIGHT SOURCE AND DETECTOR ON AN ADULT HEAD.

emission tomography (PET)—all fail to meet the basic flight requirements of low mass, low power, low volume, low crew time and low cost.

To address the technology gap for in-flight neuromedical assessment, researchers at Harvard University and Massachusetts General Hospital are developing lightweight, low-power, mobile near-infrared neuroimaging (NIN) systems that rely on the fact that near-infrared light can penetrate through several centimeters of tissue. NIN systems shine non-ionizing near-infrared light onto tissue, detect the remitted light at multiple wavelengths and use the principles of optical spectroscopy to calculate the concentration of light absorbing substances in the sampled tissue.

Hemoglobin carries oxygen to the brain and absorbs near-infrared light in proportion to the amount of oxygen it is

carrying. This allows optical measurements of brain oxygen concentration, blood volume and blood flow, which are critical variables for sensitive and specific monitoring of brain function.

The technology underlying NIN can potentially support a range of field applications. Recently, low-power electronic, laser and photodiode components have become small enough to make mobile NIN systems feasible. The most recent system, the portable NINscan device, can discriminate blood volume and oxygenation changes in the brain from those in the periphery, allowing examination of the central versus peripheral effects of microgravity on blood circulation and tissue oxygenation. This capability is key following an event resulting in low oxygen levels or altered blood flow, and in diagnosing and treating sleep deprivation, chronic stress and depression.

It is possible that mobile neuroimaging technologies such as NINscan could be used during spaceflight missions to provide clinically important information about brain physiology, either acutely in response to a critical event, or in a longitudinal monitoring application that could be sensitive to the neural effects of the psychological, physiological and environmental stressors.

On Earth, numerous applications are possible. For monitoring brain function, MRI and PET are heavy, expensive and generally restricted to major imaging centers. But systems like NINscan could be used in outpatient settings to help identify neural markers of disease, disease severity or treatment efficacy. In addition, researchers are enhancing the system robustness to subject motion, to further enable continuous and long-duration brain recordings. This would enhance the care for post-surgical, brain-injured or sleep-disordered patients. Self-contained, wearable devices such as NINscan could also afford neuroimaging in active and mobile subjects, such as those with suspected syncope, epilepsy, or those at risk for chronic subdural hematoma.

Monitoring Stress, Emotions, Fatigue

To objectively identify when astronauts may be experiencing negative stressors during prolonged spaceflight, the University of Pennsylvania School of Medicine and Rutgers University are developing an objective, unobtrusive, computational model-based tracker of astronauts' facial expressions.

Researchers there are developing an optical computer recognition (OCR) system that will provide feedback to astronauts for autonomous selection of countermeasures for stress, fatigue, or other changes in affect related to

CREDIT: NASA



THE VIRTUAL SPACE STATION IS A SELF-HELP TOOL FOR MONITORING, DETECTING AND MANAGING DEPRESSION, CONFLICT AND STRESS/ANXIETY THAT CAN OCCUR ON EXTENDED SPACE MISSIONS.

behavioral health.

The OCR project addresses long-term effects of exposure to the spaceflight environment on psychological responses, including emotional reactivity, stress responses, long-term modulation of mood and vulnerability to affective and cognitive disorders; and objective technologies that identify astronaut distress that could compromise performance capability in space. The OCR's goal is to identify these negative states and help astronauts manage the risk of behavioral dysfunction in spaceflight.

The development and validation of the OCR system has three components: an optical algorithm for real-time, dynamic facial tracking; validation of system accuracy to detect facial

expressions of stress, emotion and fatigue; and development of a feedback interface that integrates individual astronaut information over time and displays the results via a user interface for countermeasure considerations.

On Earth, the system will be highly relevant to workers in a wide range of safety-sensitive areas including transportation, power plants and military.

Self-Help Tools for Interpersonal Conflicts, Depression, Stress/Anxiety

Space crews must be somewhat autonomous to successfully complete long-duration missions, including having the ability to detect and manage medical and psychosocial problems. The Virtual Space Station (VSS) is an ongoing project to develop a behavioral health portal to help astronauts prevent, detect and manage psychosocial and behavioral problems that can arise on extended missions. Current areas being addressed are interpersonal conflict, depression and stress.

The VSS is self-guided and designed for pre-mission training and use on a laptop while on orbit. The interpersonal conflict module provides an interactive video simulation that enables users to practice managing a fictitious conflict with a virtual crew-member onboard the ISS, and conflict management training utilizes a guided, cognitive-behavioral approach.

A second portion of the VSS is self-guided treatment for depression. Using the empirically supported Problem-Solving Treatment (PST), an interactive media program approximates the

experience of a live therapy session as users are guided by a master PST practitioner. A form of clinical judgment is built into the program to better assist users in solving their own problems and thereby treating their own depression. Although the program is designed for astronauts, it could be useful to persons with limited access to behavioral health services, or who encounter barriers to treatment, such as the stigma of seeking help, providers who lack proper skills and training, and best practice guidelines not being followed.

The third VSS portion is the stress-training program, which uses a computer workshop-style approach called SMART-Op (Stress Management and Resilience Training for Optimal Performance on Long-Durations Missions). It teaches skills addressing the stress response model (triggers, thoughts, feelings and behaviors) and includes education on stress and its effects on performance and health. It also teaches behavioral coping strategies (e.g., muscle relaxation, compartmentalization, strategic problem solving). These same concepts and skills now are being utilized in the training of new astronaut candidates.

Self-Assessment Cognitive Performance Measure

Fatigue from high workload and sleep loss is a common risk to astronauts, and research has shown that fatigue risks are often not self-evident. Therefore, the development of brief, noninvasive ways to identify and assess the performance risk of fatigue in astronauts, without adding upmass, power, or other costs, is

a high priority for NASA.

The Reaction Self Test (RST) measure will help astronauts quickly and objectively identify when their performance capability is degraded by various fatigue-related conditions resulting from ISS operations and time in microgravity. The test assesses decrements in cognitive function due to fatigue and other aspects of spaceflight, determines an astronaut's vulnerability to sleep loss, establishes cognitive change during long-duration missions and facilitates ways for crewmembers to detect and compensate for decreased cognitive performance capability. Unaffected by aptitude or practice, the test rapidly informs astronauts of the need for fatigue countermeasures.

The RST was derived from the Psychomotor Vigilance Test (PVT) developed at the University of Pennsylvania School of Medicine. The PVT is a scientifically well-validated performance measure of the neurobehavioral effects of fatigue from a variety of sources.

Through NASA support, in 2009, the RST was implemented in flight on the ISS computers. During the coming years the test will be performed by up to 20 astronauts to identify how performance is affected by acute and chronic sleep restriction, slam (circadian) shifts, high workload, and time in mission.

On Earth, the tool has wide application to occupations in conditions that require high levels of alertness, such as for first responders, Homeland Security personnel, airline crews, special military operations, police and

firefighters, as well as fatigue management in a wide range of safety-sensitive occupations (e.g., transportation, manufacturing). In addition to identifying fatigue, the RST has been found to be sensitive to motion sickness and to side effects from sleep medications.

The RST software for the ISS computers, along with essential computer calibration equipment, was developed in collaboration with Pulsar Informatics Inc. In addition to NSBRI support, the laboratory studies were supported by the National Institutes of Health and the Department of Homeland Security. ■

James Carreine, Ph.D., is an instructor in medicine at Beth Israel Deaconess Medical Center, Harvard University Medical School. He developed modules for the Virtual Space Station.

David Dinges, Ph.D., is a professor in the Unit for Experimental Psychiatry at the University of Pennsylvania School of Medicine. He developed the PVT on which the Reaction Self Test is based and is co-developing the OCR system.

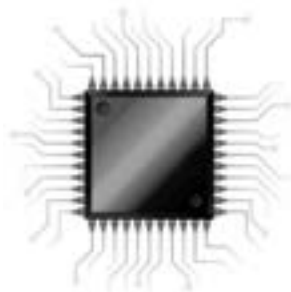
Lauren Leveton, Ph.D., is manager of the BHP Element in NASA's Human Research Program at Johnson Space Center Space Medicine Division.

Raphael Rose, Ph.D., is assistant research psychologist and clinical professor at the University of California, Los Angeles, where he and colleagues are developing the SMART-Op.

Gary Strangman, Ph.D., is assistant professor at Harvard University and leads the team developing NINscan.

For more information about the NASA BHP Element, contact Lauren Leveton at lauren.b.leveton@nasa.gov.

Please mention that you read about it in Technology Innovation.



Bioscience Benefits from NASA Laser Atmospheric Tool

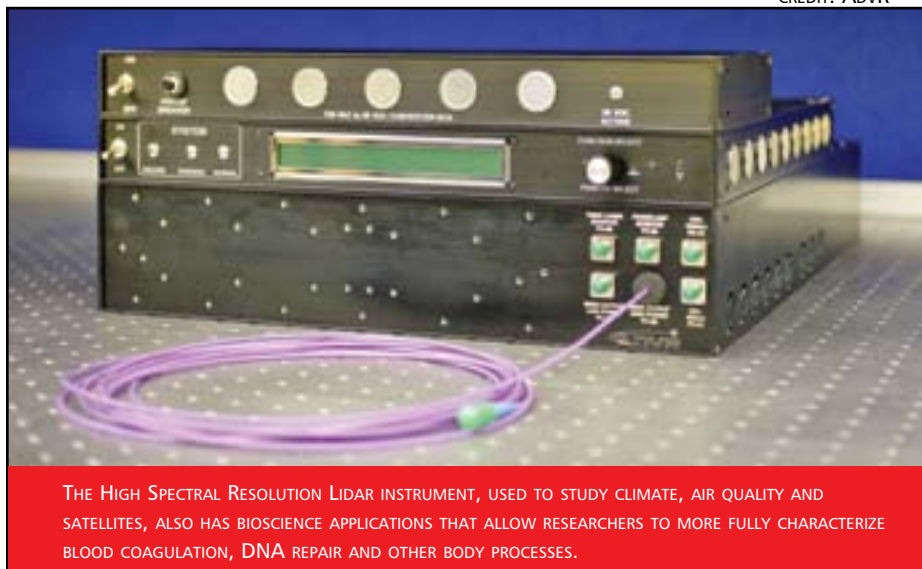
CREDIT: AdvR

By Sheri Beam
NASA Langley Research Center

As NASA studies the atmosphere surrounding our planet, its researchers are working to improve the tools they use to take more accurate measurements and collect better data. And in the process, new applications for these tools are discovered.

One such technology is the High Spectral Resolution Lidar (HSRL), a laser instrument that atmospheric scientists at NASA Langley Research Center in Hampton, Va., use for measuring cloud and aerosol properties that are relevant to climate research, air quality studies and satellite validation. As is often the case, the process of improving this technology resulted in the discovery of multiple applications for the innovation, including one in the bioscience field.

"The HSRL acquires measurements from the Langley B-200 aircraft and has flown to a variety of locations, including the Caribbean Islands, Mexico, Alaska and Canada," says Chris Hostetler, Ph.D., Langley principal investigator. "The airborne HSRL has been used extensively to validate the measurements



THE HIGH SPECTRAL RESOLUTION LIDAR INSTRUMENT, USED TO STUDY CLIMATE, AIR QUALITY AND SATELLITES, ALSO HAS BIOSCIENCE APPLICATIONS THAT ALLOW RESEARCHERS TO MORE FULLY CHARACTERIZE BLOOD COAGULATION, DNA REPAIR AND OTHER BODY PROCESSES.

made by NASA's CALIPSO satellite-based lidar and is an early prototype for the next-generation space-borne lidar to be flown on the Advanced Composition Explorer mission."

In May, it was flown over the over spill in the Gulf of Mexico to help investigate potential uses of satellites for monitoring the thickness and dispersal of oil spills.

A Unique Technology

Through NASA's Small Business Innovation Research (SBIR) program, AdvR Inc. (www.adv-r-inc.com), of Bozeman, Mont., partnered with engineers at Langley to develop com-

pact, lightweight, electro-optic components for lidar-based remote sensing instruments.

AdvR recently developed an optical waveguide circuit that integrates several key functions into a rugged, compact module for the laser transmitter in Langley's HSRL. A waveguide is a physical structure that guides electromagnetic waves in the optical spectrum. The AdvR module has been successfully integrated into a next-generation seed laser system, which provides the precise wavelength stability required for HSRL measurements.

According to Anthony Cook, HSRL lead engineer at Langley, "The AdvR

technology is unique in that it combines two optical functions in one compact, robust chip that precisely locks the laser to the required wavelength. Precise locking of the laser and filter wavelengths is critical to the accuracy of the geophysical products that we derive from the acquired data.”

NASA’s HRSL personnel are using the AdvR technology in lab tests to verify full-system operation. The first official flight operation of one of the AdvR-developed systems will take place this year on NASA’s King Air B-200 aircraft, based at Langley. The plane is equipped with a suite of state-of-the-art Langley-developed sensors that help scientists study and better understand Earth’s atmosphere and air quality.

In addition to its primary use at Langley, the technology has other applications within NASA and the commercial marketplace. For instance, AdvR partnered with Berlin, Germany-based PicoQuant, a leader in the field of diode lasers and fluorescence systems, to develop a new laser source that integrates a component of the original SBIR concept as a part of the laser module.

Bioscience Applications

The commercially available PicoQuant pulsed laser is used for a variety of applications, including several in the bioscience field. Researchers are now able to more fully characterize different processes in the body, such as blood coagulation and repair of damaged DNA, through the use of the PicoQuant laser and powerful techniques, including time-resolved fluo-

rescence spectroscopy and microscopy.

The laser is being utilized in laboratories including the NIH-funded COBRE Center in Missoula, Mont., where researcher J.B. Alexander (Sandy) Ross, Ph.D., is studying how blood coagulation is initiated at a molecular level, a process critical in bleeding disorders and stroke. For example, Dr. Ross tags the blood proteins that participate in initiation of blood coagulation with fluorescent dyes, which are probes for interactions of interest. When pulsed light of the proper excitation wavelength illuminates the probes, they glow with lifetimes of a few nanoseconds, and he is able to characterize the time-dependent behavior of the process of interest.

Various dyes are required to fully characterize the behavior, and specific dyes that require an excitation wavelength of 530nm will allow Dr. Ross to more fully characterize the processes of interest, and now that a given excitation wavelength is available, Dr. Ross is able to use fluorescent probes that help him more fully characterize the blood coagulation process. Through his work, he hopes to provide information that will help enhance or slow down the process for specific medical applications, such as control of clot formation during a stroke or bleeding resulting from tissue damage.

In addition to applications in bioscience, the technology has NASA applications as well. Some are in NASA’s other lidar remote sensing programs, such as in altimetry and differential absorption lidar (DIAL) at NASA’s

Goddard Space Flight Center, where compact, low-cost, stabilized single-frequency lasers in the visible and UV wavelengths are required.

Other applications are for *in-situ* planetary studies in JPL’s planetary science program, where compact, high-power green laser sources are needed for the Mars Microbeam Raman Spectrometer.

The benefits to NASA and to the public through commercialization are a tribute to the SBIR program through which the technology was further developed.

“The SBIR programs have been very beneficial to this technology development, as it was through these programs that the initial fusion of our waveguide technology with opto-electronic packaging was developed,” says Shirley McNeil, senior laser systems engineer at AdvR.

McNeil also sees other applications for AdvR SBIR-developed technology: “There are additional commercial applications, such as for the laser-based display and TV markets, and we are actively seeking industrial partners to utilize our component level products.” ■

Sheri Beam is in the Strategic Communications Office at Langley Research Center.

For more information, contact Anthony Cook at a.l.cook@larc.nasa.gov.

Please mention that you read about it in Technology Innovation.



National Space Biomedical Research Institute: Conducting “Down-to-Earth” Space Research in Health and Medicine

By Dennis J. Grounds
NASA Johnson Space Center

Jeffrey P. Sutton, M.D., Ph.D.
National Space Biomedical Research Institute

In the mid-1990s, NASA launched a competition to form an academic research consortium tasked with engaging the brightest minds at the nation's leading universities, medical schools and research laboratories.

The objective: Find solutions to the health challenges of long-duration space flight and spin off benefits to medical care on Earth.

The result: Selection and founding of the National Space Biomedical Research Institute (NSBRI) (www.nsbri.org).

From NSBRI's inception in 1997, what evolved is nothing short of a major success story for NASA.

The Institute, in partnership with NASA, leads a national effort to ensure safe and productive long-term human presence in space and to enhance life on Earth by applying the resulting advances in human knowledge and technology. The products generated by the outstanding physicians, scientists and engineers are innovations in health care

and technology that benefit both space travelers and Earth-based medicine and research.

NSBRI is governed by a consortium 12 institutions – Baylor College of Medicine, Brookhaven National Laboratory, Harvard Medical School, The Johns Hopkins University, Massachusetts Institute of Technology, Morehouse School of Medicine, Mount Sinai School of Medicine, Rice University, Texas A&M University, University of Arkansas for Medical Sciences, University of Pennsylvania Health System, and University of Washington. In general, about half of NSBRI's projects are funded at member institutions, and half at non-member institutions or companies.

The NASA-NSBRI partnership leverages the nation's investment in biomedical research and implements a new model for how academia, industry and government work together to achieve scientific, technological and educational

progress and deliverables at the interface of space life science, medicine and space exploration. Individual NSBRI-funded projects often have relationships with other agencies, industry partners, and other funding sources, such as the Department of Defense and NIH.

The partnership is balanced in that NASA maintains a strong cadre of scientific expertise that remains cognizant of the past, present and expected health and performance issues with astronauts. The relationship between NASA scientists and physicians and NSBRI scientists and leaders is strong and keeps the overall focus on the highest risks to space explorers. This relationship is maintained through frequent communication at multiple levels, involving individual scientists, team leaders, scientific discipline and element leads, and top management. Additionally, the entire NASA and NSBRI human research community gathers annually at a program work-

GOVERNMENT AGENCY PARTNERSHIPS WITH NASA

CREDIT: PATRICK WRIGHT/CLEMSON UNIVERSITY



NSBRI INVESTIGATORS REVIEW 3-D IMAGES OF BONE AS PART OF A PROJECT LOOKING AT THE EFFECTS OF SPACE RADIATION AND DECREASED WEIGHT BEARING ON BONE LOSS. THE PROJECT WILL DETERMINE WHICH TREATMENTS CAN REDUCE THE LOSS OF BONE AND LOWER THE RISK OF FRACTURES. THE RESEARCH HAS EARTH-BASED APPLICATIONS IN DISEASES SUCH AS OSTEOPOROSIS.

shop to exchange results, examine questions of integrative physiology and renew understanding of recent developments in health and performance issues.

NSBRI's focus is on deliverables, and Institute investigators work on interdisciplinary teams to add value to science and technology projects. Collaborations with industry are common, to more rapidly achieve products for NASA and for commercial or medical use. Several of NSBRI's current projects are awarded to principal investigators at corporations, and the Institute has an active Industry Forum.

Accelerating Findings

NSBRI's translational research program aids NASA's Human Research Program by accelerating the transfer of findings from the laboratory to space flight and clinical applications. The product-oriented approach to research and development is leading to a number of operationally relevant countermeasures and technologies that are ready for testing and evaluation aboard the International Space Station (ISS) and in medical settings.

Projects are openly solicited, peer reviewed and competitively awarded with a priority on activities that show

high promise for translating biomedical knowledge to needed countermeasures and useful health care tools. NSBRI's seven integrated science and technology teams unite the scientific and clinical expertise and resources of the nation's biomedical research community with the scientific, engineering and operational expertise of NASA.

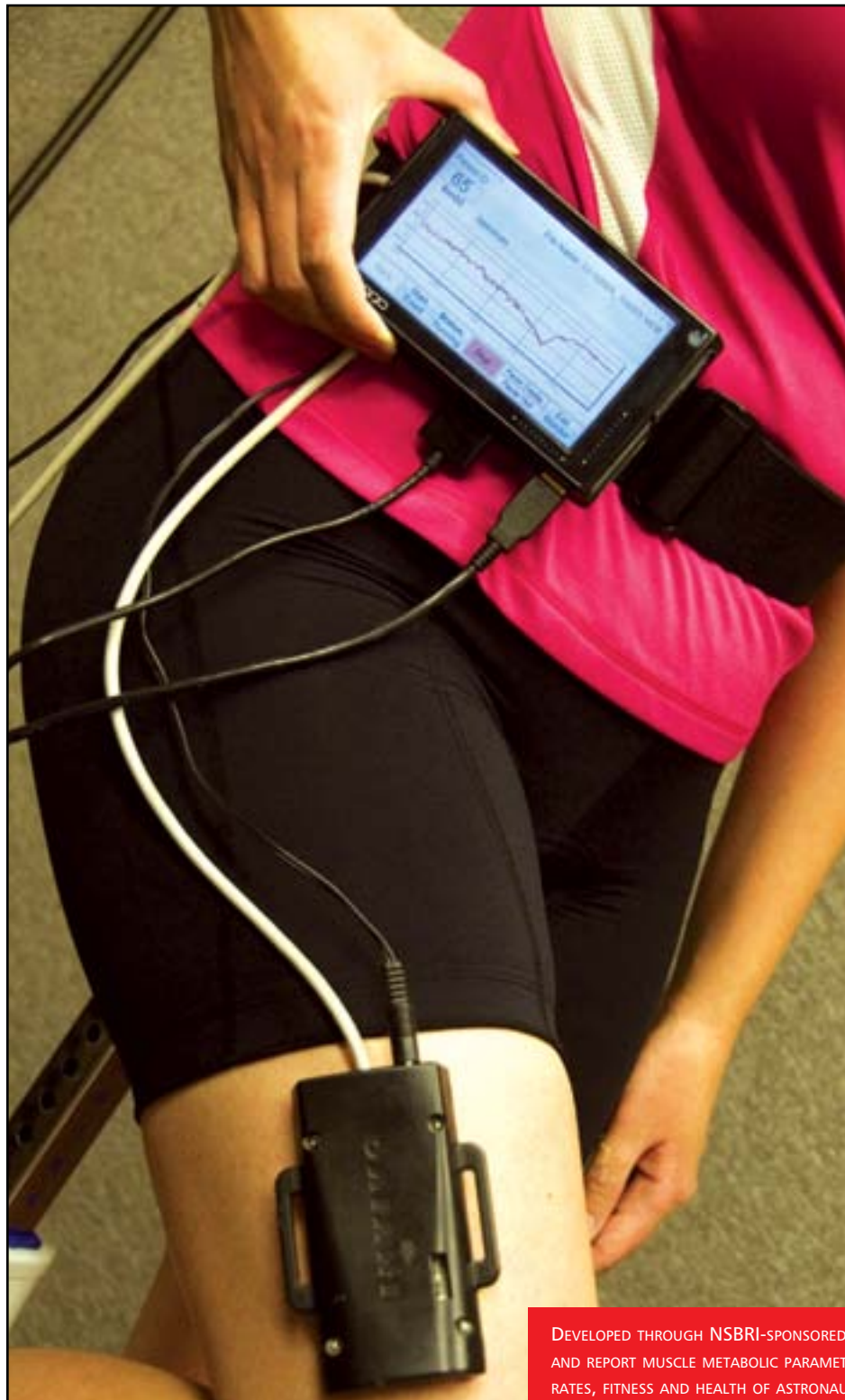
Key working relationships are established with end users, including astronauts and flight surgeons, and with NASA scientists and engineers. This broad base of stakeholders ensures that NSBRI's research and development program meets NASA's requirements and that the highest biomedical risks within the Human Research Program are addressed and reduced.

In the coming year, NSBRI plans to open a Consolidated Research Facility that will support improved and accelerated testing and evaluation of medical countermeasures and technologies under development for NASA. This facility, in collaboration with Baylor College of Medicine's Center for Space Medicine, will provide a Houston laboratory to the NSBRI community as it readies projects for transfer to operational testing in collaboration with NASA. The facility will serve as a setting for NSBRI investigators to showcase their work to potential industry partners who are interested in commercializing technology. It also will provide an academic home for faculty, staff, students and others within the largest medical center in the world, to engage

Innovator s Corner

GOVERNMENT AGENCY PARTNERSHIPS WITH NASA

CREDIT: LUIGI PIARULLI



in research, education and clinical opportunities at the interface of space and medicine, and in close geographical proximity to and in collaboration with NASA Johnson Space Center.

Success Story – Metabolic Sensor

The NASA-NSBRI partnership has yielded many successes in developing technologies for space with applications on Earth. Some examples include a portable radiation detector that can be used by individuals in radiation oncology and homeland security; ultrasound that assesses bone parameters beyond density to include bone strength, structure and stiffness; and blue-enriched lighting for treatment of sleep problems.

Another example, which is nearing readiness for testing on the ISS, is the NSBRI project of Babs R. Soller, Ph.D., University of Massachusetts Medical School. The device, a small, noninvasive, spectroscopic sensor, can continuously measure and report muscle metabolic parameters that are important in assessing the metabolic rate, fitness and health of astronauts and Earth-bound patients. The sensor also can be used to measure muscle oxygen levels, an early indicator of undetected internal bleeding, and muscle pH levels, which would provide feedback on adequacy of therapy to address poor oxygen delivery resulting from bleeding or sepsis. The project

DEVELOPED THROUGH NSBRI-SPONSORED RESEARCH, THIS SPECTROSCOPIC SENSOR CAN MEASURE AND REPORT MUSCLE METABOLIC PARAMETERS THAT ARE IMPORTANT IN ASSESSING THE METABOLIC RATES, FITNESS AND HEALTH OF ASTRONAUTS IN SPACE AND PATIENTS ON EARTH.

GOVERNMENT AGENCY PARTNERSHIPS WITH NASA

leveraged NSBRI and Department of Defense funding to accelerate its development and has undergone ground testing involving stationary cycling, treadmill walking and running at Johnson Space Center.

Value to NASA: The sensor will reduce the crew's set-up time for activities requiring the on-orbit metabolic cart. It also will provide real-time feedback to astronauts on the effectiveness of routine exercise. In time, it may allow astronauts to optimize exercise to preserve muscle strength and aerobic capacity. Although the device was envisioned for use during routine exercise, all crew members would also be trained on its use in response to a medical emergency.

Value to Earth: The sensor can assist emergency and critical care physicians in the diagnosis and treatment of critically ill patients, and it holds promise for use in air and ground ambulances and on the battlefield. The device also has a general medical application for diagnosis of anemia and chronic heart problems. The muscle metabolic measurements may one day assess physical therapy used in rehabilitating patients with muscle injury or atrophy. It could be used in the training of athletes and for cost-effective health care to adults and children, including those in remote areas.

Maximizing America's Potential

The NASA-NSBRI partnership is firmly committed to a strong education program that spans from elementary grades to clinical research training in space

medicine and beyond. The program supports NASA's educational objectives and the nation's priorities for improving science, technology, engineering and mathematics education.

Educational activities focus on developing curricular materials; deploying Web-based resources for teachers and faculty; implementing workshop-based teacher professional development programs; and supporting summer internship, graduate education and postdoctoral fellowship programs.

The education program received a Stellar Award from the Rotary National Award for Space Achievement Foundation recognizing "performance as a nationally recognized, top-tier program that is pioneering new models for exemplary teaching, training and public outreach in support of space exploration."

The "Butterflies in Space" educational activity, a recent partnership between NSBRI, NASA, Baylor College of Medicine and BioServe Space Technologies, provided classrooms with real-time images of Painted Lady butterfly larvae developing on the ISS. By following instructions in a downloadable teacher guide, classrooms set up ground-based butterfly habitats and compared larvae developing on Earth to those on the space station. The experiment drew participants from every state and more than 23 countries, using a project Web site and the social media tools Facebook and Twitter to alert participants of the

arrival of new imagery from space. Photos and video transmitted from space were archived on the Butterflies in Space Web page, allowing classrooms to replicate the experiment for years to come.

Future Directions

NASA created NSBRI with a bold, forward-looking vision and has fostered the Institute's evolution into a world-renowned, premier science institute. NSBRI has demonstrated the productivity and flexibility of its science, technology and education programs to have high impact for the nation's human space program. Other countries have begun to emulate the model, given its successes, effective collaborations and low management costs. NSBRI is well positioned to contribute science and technology advances during the utilization phase of the ISS. Together with NASA, NSBRI will continue its emphasis on excellence in research, education, outreach and improving life on Earth. ■

Dennis J. Grounds is manager of NASA's Human Research Program, headquartered at Johnson Space Center. Jeffrey P. Sutton, M.D., Ph.D., is director of the National Space Biomedical Research Institute.

For more information about the NSBRI and its programs, including those discussed in this article, visit www.nsbri.org, or email info@nsbri.org.

Please mention that you read about it in Technology Innovation.

Facility Focus

Biomedical Laboratory Tackles Health & Safety Issues

By Donald Doerr
NASA Kennedy Space Center

Carol Anne Dunn
NASA Kennedy Space Center

Ensuring the health and safety of astronauts is of utmost importance to NASA. But just as vital to the Agency is looking after the condition of ground processing personnel working outside in the heat and noise at Florida-based John F. Kennedy Space Center, NASA's primary launch and landing site.

A wide variety of health and safety issues affecting these two groups is addressed in the Biomedical Laboratory at Kennedy. Established during the Apollo era, the lab has provided biomedical support to major manned space programs including Apollo, Apollo-Soyuz, Skylab and the space shuttle.

While NASA Johnson Space Center in Houston, Texas, is primarily responsible for flight experiments and astronaut health, the Biomedical Lab provides support at Kennedy in the physiological testing of humans, particularly space vehicle processing personnel on the ground. The lab investigates countermeasures such as respiratory protection, whole body suit ensembles, hearing protection, and heat stress solutions, among others.

Closely related to this mission, the lab is also responsible for checkout and maintenance of flight and ground biomedical monitoring instrumentation systems. This includes instrumentation systems on the spacecraft and the displays in the launch control center.

Because the lab often evaluates various forms of commercial off-the-shelf life support equipment, it works closely with private companies. Having seen the space program's unique need for advanced forms of personal protective equipment, some companies have responded with new designs based on the commercial potential of these advances.

CREDIT: NASA



AT KENNEDY SPACE CENTER'S BIOMEDICAL LABORATORY, A KOOLVEST™ UNDERGOES TESTING IN A 110-DEGREE ENVIRONMENTAL CHAMBER TO DETERMINE WHETHER IT WOULD HELP TO COOL WORKERS LABORING IN A PROPELLANT HANDLER'S PROTECTIVE SUIT.

Noise Environment Advances

Several of Kennedy's operational work environments challenge occupational noise standards. While workers use effective forms of hearing protection that meet Occupational Safety and Health Administration (OSHA) requirements, these devices have not always been practically assessed in the actual work environment. The Biomedical Laboratory recently established *in-situ* methods to determine the actual effectiveness of noise protective equipment.

A recent example was testing of a hose-line supplied self-contained atmospheric protective ensemble (SCAPE). In this project, the lab evaluated the two available communications headsets – the Snoopy Communication Carrier and the wire frame headset. OSHA requires the institution of “engineer-

ing controls” as the first line of defense, but failing this, personal protective equipment is needed. In this case, an “engineering control” was investigated, one specifying the replacement of convoluted air distribution hose with a smooth bore hose. This resulted in reduction of noise by 13 dBA.

Since the noise was still too high, testing focused on the two available communications headsets used within the suit. Quite surprisingly, a commonly used wire-frame headset did not offer adequate hearing protection, and this headset was removed from the inventory. Testing of the alternative Snoopy-style headset revealed more-than-adequate protection.

While these protective measures protect the worker in the field, these same situations create a problem when communications originating from a noisy location is transmitted to other test team members via operational intercom and radio systems.

The Biomedical Lab conducted a study on a noise reduction methodology using digital processing techniques. The intent was to detect and filter out the environmental noise prior to transmission.

In one project, two noisy environments were tested – the SCAPE suit mentioned previously, and the M-113 armored personnel carrier used for astronaut rescue at launch pad 39.

A prototype Digital Signal Procession (DSP) system was constructed and inserted into the microphone line. Field testing of this system in both locations was accomplished using a Bruel and Kjaer Head and Torso Simulator (HATS), which provided reproducible signal source for the microphone and noise spectrum data. The tests demonstrated the effectiveness of DSP techniques that make dramatic improvements in communications intelligibility, while reducing broadcasted environmental noise.

In December 2009 similar DSP techniques were tested successfully with another type of SCAPE suit at the Cape Canaveral Air Force Station Propellants Farm using that facility’s radio system. The DSP now is planned to be included in the upgrade of the radio system expected in 2010.

Understanding Heat Stress

The environmental control units (ECUs) in SCAPE suits use liquid air to provide both breathing air and some cooling to the wearer; however, Florida’s summer ambient conditions

often exceed the cooling capacity of the ECU.

In looking for another solution, the Biomedical Lab tested the efficacy of the Koolvest™, manufactured by Respirex Inc. of London. The Koolvest contains inserts of nontoxic phase change material (PCM) that remove heat from the vest wearer.

This study involved 10 research volunteers performing various tasks, representative of SCAPE operations, for one hour in a 110°F environmental chamber. They completed the SCAPE work protocol twice, once while wearing the Koolvest and once without. Conditions were randomized and tests were separated by at least seven days. The subjects were instrumented to measure five skin temperatures, body core temperature and heart rate. They were weighed before and after testing to determine sweat loss due to perspiration. Results showed that subjects had significantly smaller rises in core temperature and lost significantly less weight when they wore the Koolvest. Test conductors, who were exposed to the same high temperatures, also benefited from wearing the vest even though they were wearing normal athletic gear.

Collaboration and Support

The Biomedical Lab collaborates with other NASA labs, other government agencies and industry. Partners include NASA Ames Research Center, the European Space Agency, the U.S. Army Institute for Surgical Research, the U.S. Air Force School of Aerospace Medicine, the U.S. Navy Experimental Diving Unit, the Veterans Administration and several private companies.

The lab’s ultimate objective is to improve the health and safety of personnel in the workplace, with the expectation that many of the developments be transferred beyond the space program to industry, thereby benefiting the nation. ■

Donald Doerr is chief of the Biomedical Lab at Kennedy Space Center. Carol Anne Dunn is a project specialist at Kennedy.

For more information contact Donald Doerr at don.doerr-1@nasa.gov.

Please mention that you read about it in Technology Innovation.

From Snow to Space, Cell Imaging Finds Its Place at NASA

By David Basiji, Ph.D.
Amnis Corporation

Nathan Bramall, Ph.D.
SETI, NASA Ames Research Center

Anna Bui
NASA Ames Research Center

Microscopes have existed for more than 300 years and can be found in every biology laboratory in the world. However, researchers interested in blood cells and other suspended cell samples had never been able to study these cells under a microscope without first smearing them on a glass slide. This needed step changes the appearance of the cells. In addition, because a typical microscopist only looks at some 200 cells on a blood smear, he or she might not find rare cells that take more searching to locate.

These limitations were addressed in 2005 with the introduction of the ImageStream® system by Seattle-based Amnis Corporation (www.amnis.com). ImageStream could take six simultaneous images of each cell, using three different forms of microscopy, directly in flow, and at rates of 100 cells per second. Despite the speed and flow format, the image quality of the ImageStream was comparable to standard microscopes employing 40X magnification. These new capabilities

allowed researchers in immunology, oncology and hematology to image millions of cells at a time to identify and study extremely rare cells within their complex samples.

However, a standard microscope could do one thing that the ImageStream could not: change focus up and down through a cell on a slide to find small structures or signals that might lie outside of the plane of focus. In order to address this limitation, Amnis applied for a Small Business Innovative Research (SBIR) contract from NASA to develop and evaluate several techniques to extend the ImageStream's depth of focus. The SBIR contract was awarded in May 2005.

Amnis' contract called for the evaluation of three different methods of achieving extended depth of field (EDF) operation. Two of the methods were developed in-house, and the third was developed by CDM Optics of Boulder, Colo. The evaluation showed that all three methods were effective, but the CDM method had the advantage of being easily engaged or disengaged in seconds, whereas the two in-house methods required that the system always be run in EDF mode. Because EDF operation is not necessary or even desirable for every cell imaging task, and

the ImageStream was designed for

a wide range of imaging

applications, Amnis concluded that the CDM method was best suited for commercialization.

The CDM method involves the placement of a small, saddle-shaped, clear element in the ImageStream's opti-

cal train. The element is designed to blur any signal within the cell to the same degree, regardless of how out of focus the signal is. The system is calibrated by imaging extremely small particles that produce a reference blur pattern called a "focus-invariant point spread function." In a process very similar to the one that is used to sharpen the initial data from the Hubble Space Telescope, the calibrated point



CREDIT: AMNIS CORPORATION

THE IMAGESTREAM HIGH-SPEED IMAGE FLOW CYTOMETER PROVIDES A HIGHER-RESOLUTION VIEW OF CELLS AND THUS CAN SPOT ABNORMALITIES EARLIER THAN IS POSSIBLE WITH CURRENT TECHNOLOGY. EARLIER DETECTION COULD LEAD TO AN INCREASED CHANCE OF SURVIVAL.

CREDIT: NASA



spread function is mathematically deconvolved from the ImageStream data to recover clear cell imagery that preserves the focus invariance imparted by the EDF optical element.

After extensive work to optimize the calibration routine and deconvolution algorithms, Amnis commercialized an EDF upgrade that could be installed on any ImageStream system. The EDF upgrade allows the ImageStream to keep the entire cell in focus as it flows through the instrument, and it has the added benefit of allowing the ImageStream to image cells two to three times faster. EDF operation can be defeated simply by moving the EDF element out of the optical path via a motorized filter wheel.

In November 2006, Amnis shipped an ImageStream instrument equipped with the EDF upgrade to NASA's Ames Research Center in Mountain View, Calif., where the

instrument is still in use today to study the pigmentation, development and morphology of snow algae collected from Lassen National Park. Both field samples and cultures are being studied in conjunction with single-cell polymerase chain reaction. The study of cultures allows for a very rapid and quantitative way to map out the life cycle of the snow algae under different controlled conditions, while the study of field samples allows for the rapid assessment of populations, dynamics and life cycles within the snow pack over a function of time.

The technology provides a view of cells that is of a much higher resolution so that when used in a biomedical setting, abnormal cells or those with signs of cancer can be spotted sooner, leading to an earlier diagnosis and higher chances for survival.

Since the development of the EDF upgrade, Amnis has come out with a second-generation ImageStream system that can analyze 1,000 cells per second. It generates 12 simultaneous images per cell, operates at both 60X and 20X magnification in addition to the standard 40X, and is priced lower than the first-generation instrument. The EDF option has been carried over to the new product. Amnis envisions numerous uses for the ImageStream in NASA programs, including the evaluation of astronaut health on the ground, in orbit and in extended flight. The company has plans to develop a smaller, lighter and more power-efficient system that would be well-suited to low- and zero-G operation and will be seeking a follow-on contract with NASA for the development of this platform. ■

David Basiji, Ph.D., is president and chief executive officer of Amnis Corporation. Nathan Bramall, Ph.D., is an SETI researcher in the Space Science Division at NASA Ames Research Center conducting studies with the ImageStream system. Anna Bui is the NASA SBIR program outreach coordinator based at Ames Research Center.

For more information, contact David Basiji at basiji@amnis.com.

Please mention that you read about it in Technology Innovation.

Open Innovation: A New Business Model for NASA's Space Life Sciences Directorate

By Jeffrey R. Davis, M.D.
NASA Space Life Sciences Directorate

Karim R. Lakhani, Ph.D.
Harvard Business School

Elizabeth E. Richard
Wyle Integrated Science and Engineering Group

In May 2007, NASA's Space Life Sciences Directorate (SLSD) at the Johnson Space Center (JSC) published its strategic plan, identifying as key strategies the need to collaborate with external entities and to adopt new business models to most effectively achieve its goals of driving innovation in health care and performance for human space flight.

In implementing its plan, the SLSD is exploring various models for collaboration. In conjunction with the JSC Advanced Planning Office, SLSD conducted a benchmark to assess best practices in establishing and managing alliances, and to learn how organizations use collaboration to drive innovation. Subsequently, SLSD partnered with Professor Karim Lakhani of Harvard Business School (HBS) to conduct an MBA student project to evaluate the directorate's potential for utilizing open or distributed innovation.

These efforts indicated that alliances and other collaborations are crucial to driving innovation. Organizations use collaborations to innovate quickly and cost effectively, improve the quality of innovation, and enhance their portfolios by supplementing internal capabilities with external capabilities. The result is a transfer of compatible competencies, knowledge and risk sharing, access to new technologies, and accelerated research that adds variability resulting in novel ideas.

SLSD also partnered with the HBS to determine which

gaps or needs in its research, technology and operations portfolio would be best suited to various collaborative approaches, and which capabilities should be developed internally. Eleven portfolio gaps were mapped to various collaborative modes based on an HBS-developed model, resulting in the identification of several targeted "open innovation" initiatives. Open innovation is based upon the assumption that organizations can more effectively innovate using external ideas in addition to internal ideas.

Because using a deliberate, structured approach is critical for effective collaboration, SLSD also is developing its own system of innovation aimed at closing its gaps based on the highest priority human system risks. Employing open innovation as a strategy for achieving its goals is just one tool in SLSD's evolving business model, and several efforts utilizing this approach are currently underway.

Open innovation service providers, or intermediaries, have emerged in recent years to provide organizations with a mechanism for connecting with outside experts to solve problems.

SLSD is currently piloting two initiatives in which an open innovation service provider matches an organization's (SLSD's) needs, or challenges, with a network of problem solvers to provide an efficient, cost-effective solution. SLSD sought and obtained funding for the project, and selected two companies through a competitive process to test this approach.

The first open innovation service provider selected was InnoCentive (<http://gw.innocentive.com>). The company posts individual challenges to their established Web network of solvers, seeks viable solutions for predefined periods of time, and grants a financial award to solvers who provide the best solutions to meet the challenge criteria. Three of SLSD's human health and performance challenges were posted in December, aimed at forecasting solar events, keeping food fresh in space and developing a mechanism for a compact resistive exercise device. Interest in the NASA challenges was very high—as determined by the number of "project rooms" that opened up in which potential solvers work on solutions. Other NASA organizations are now considering posting additional challenges.

"Many people around the world did not previously have the opportunity to help solve some of the problems facing NASA," said InnoCentive CEO Dwayne Spradlin. "Now,

anyone with interest and ability can impact how the U.S. explores the final frontier. NASA Space Life Sciences' commitment to open innovation is a testament to exploring solutions from any contributor."

In January, SLSD posted with Yet2.com (www.yet2.com), the second open innovation service provider selected. The posting was for a technology need seeking accurate measurement techniques for bone density and structure.

Yet2.com acts as an actual technology scout by searching their network of companies, development organizations and experts for potential solutions based on the specific challenges or gaps, bringing together buyers and sellers of technologies who then establish technology development partnerships.

"Our network and expertise is focused around relatively mature technologies and we have previously supported Air Force Research Laboratory on their open innovation initiative," commented Eugene Buff, Yet2.com vice president of consulting. "We actively scout the world of technologies and hope to bring valuable innovation to NASA on this and other challenges planned for this program."

A third SLSD innovation project is an experimental programming competition in partnership with TopCoder (www.topcoder.com), HBS and the London Business School (LBS). TopCoder offers competition-based software development using a unique model of open innovation referred to as open source through its established software development community.

In this experiment, funded by grants from HBS and LBS, competitors develop algorithms to help NASA make decisions involved with optimizing the contents of a medical supplies kit that may be carried onboard long-term space missions. SLSD's role was to provide a compelling technical challenge for analysis from an open innovation management perspective.

The project resulted in 5,995 code submissions from 1,098 programmers from around the world, and the results are being analyzed. Submissions were compared with the results of

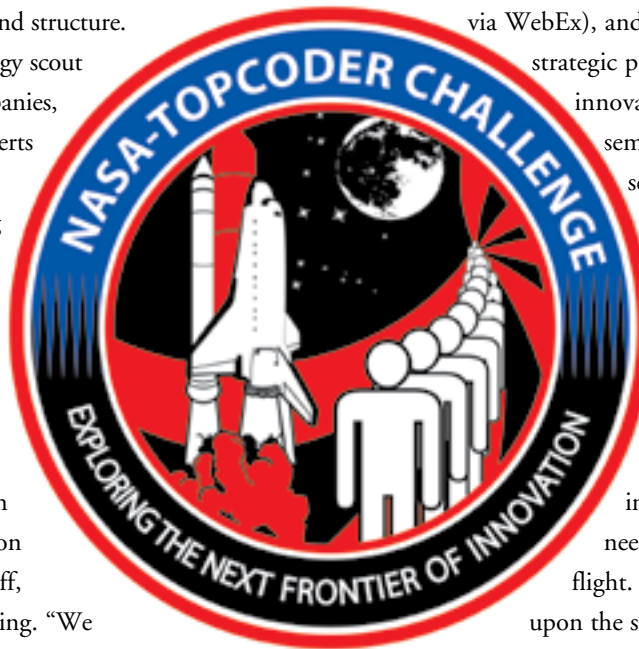
an existing computer model that has simulated the expected medical occurrences and outcomes for various mission scenarios, as well as to assess the diversity of approaches.

In addition to applying various open innovation models, SLSD also is assessing collaborative research approaches, communicating the benefits of collaborative innovation through its Innovation Lecture Series (available NASA-wide via WebEx), and continuing to work on additional

strategic projects with HBS to pursue its innovation goals. For the spring 2010 semester, HBS added a course for second-year MBA students on "Managing Innovation," which includes projects to develop innovation approaches for SLSD exercise and food technology programs.

HBS students and faculty are very enthusiastic about collaborating with NASA scientists and engineers on issues related to human space flight. Ultimately, SLSD plans to build upon the successes of these partnerships and

open innovation efforts to implement a deliberate system for innovation throughout the directorate. The strategy is to develop new business models to drive innovation, and by collaborating with academia and industry, SLSD is infusing novel technologies and approaches into its portfolio. ■



Jeffrey R. Davis, M.D., is director of NASA's Space Life Sciences Directorate, a technical organization of nearly 1,000 individuals in science, medicine, engineering and development. Karim R. Lakhani, Ph.D., is assistant professor at the Harvard Business School and faculty associate of the Berkman Center - Harvard University. Elizabeth E. Richard is senior strategist for Wyle Integrated Science and Engineering Group, focusing on strategy development and execution for SLSD.

For more information contact Jeffrey Davis at jeffrey.r.davis@nasa.gov or Elizabeth Richard at erichard@wylehou.com.

Please mention that you read about it in Technology Innovation.

Opportunities for Partnership

Technologies are available for licensing and joint development at each of the NASA Field Centers through their Innovative Partnerships Program (IPP) offices. Provided here are details on a sampling of numerous available technologies. Read more about other new technologies each month in NASA TechBriefs (www.techbriefs.com), and for a comprehensive list, go to <http://ipp.nasa.gov>.

Nanotechnology for Encapsulation of Implantable Medical Devices

NASA's Ames Research Center has technology based on carbon nanotube Bucky Paper to form capsules that shield cells, tissues or medical devices for transplantation purposes. The highly porous mesh structure of the capsules allows for the free flow of nutrients and metabolites, providing a suitable environment to maintain living cells. The primary purpose of the invention is two-fold: (1) to shield cells or devices from the host immune system, thereby removing the need for immunosuppressive drugs, and (2) to provide a structure to facilitate controlled secretion of therapeutic substances from transplanted cells for gene therapy applications.

Technology Details

Bucky paper capsules measuring 1-3 mm in diameter can be implanted at a wide range of anatomical sites. Both cell and tissue biocompatibility have been demonstrated, including subretinal implantation experiments in rabbits, which showed no inflammation. Pore size can be controlled to retain transplanted cells and to ensure that immune effector cells are excluded. Gas permeability has been demonstrated, which is important for oxygen and



CARBON NANOTUBE BUCKY PAPER IS SHOWN ON THE LEFT PRIOR TO IMPLANTATION. ON THE RIGHT IS A SCANNING ELECTRON MICROSCOPE (SEM) IMAGE SHOWING THE PAPER'S POROUS, MESHWORK STRUCTURE.

CREDIT: NASA

carbon dioxide transport. Also demonstrated have been favorable protein dissociation characteristics. A wide variety of chemical modification techniques is available, which may serve to enhance the characteristics of the capsules for specific applications.

Benefits

Major competitive advantages over other encapsulation materials in development for islet cell transplantation and other applications:

- High degree of biocompatibility with a variety of cells and tissues
- Excellent "engineerability" – can control density, porosity and shape to optimize for specific applications
- Capsules can be produced cheaply from bulk preparations of carbon nanotubes, reducing materials and manufacturing costs
- Potential for gene therapy applications without the need for viral vectors

- Large market size – diabetes has a total estimated U.S. market of \$15 billion, medical device implants have a total estimated U.S. market of \$27.9 billion

Applications

- Encapsulation of islet cell transplants for treatment of diabetes
- Encapsulation of engineered cells for gene therapy applications
- Immune shielding of implantable medical devices or drug delivery devices ■

For more information and details about licensing this technology please contact William M. Toscano in the Entrepreneurial Initiatives Division of NASA Ames Research Center at (650) 604-0894 or William.M.Toscano@nasa.gov. Please reference Case Number ARC-15088-1.

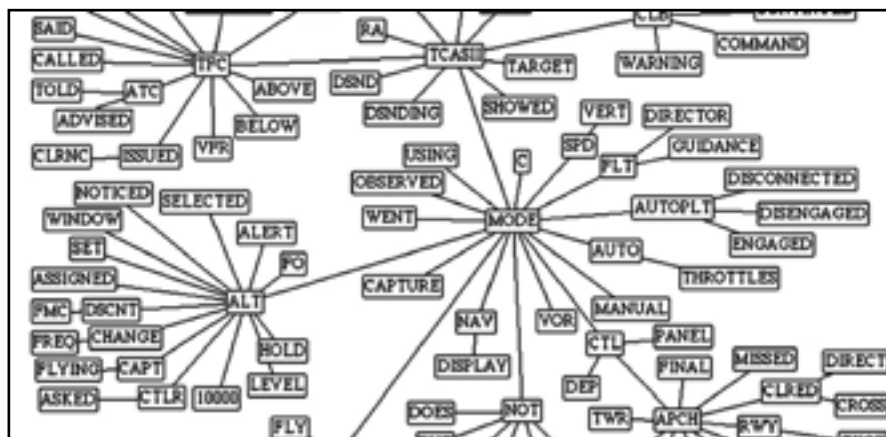
Please mention that you read about it in Technology Innovation.

Perilog – A Contextual Search Method for Improving Search Results

NASA's Ames Research Center offers for license its patented Perilog software, a contextual search method that provides a simple-to-use means of finding and ranking text documents according to their relevance to particular words or phrases. Rather than simply finding documents that contain particular words or phrases, Perilog finds contextual associations between words and phrases. This ability enables conceptual and semantic search without the need to maintain categorization for the documents. Users are able to quickly identify related topics, even if those topics do not co-occur in the same document and the user has no prior knowledge of the documents. Perilog can be used for a wide range of conceptual search and semantic search applications – in knowledge management systems, as enhancements or add-ons to commercial search engines and for contextual advertising solutions.

Technology Details

Perilog's underlying algorithm is based on the theory of experiential iconicity, which states that patterns of relatedness among things in the world of experience systematically influence



THE PERILOG SOFTWARE ALLOWS A CONTEXTUAL SEARCH THAT FINDS AND RANKS TEXT DOCUMENTS ACCORDING TO THEIR RELEVANCE TO WORDS OR PHRASES. APPLICATIONS INCLUDE MEDICAL RESEARCH, INTELLIGENCE ANALYSIS, AIRLINE FLIGHT SAFETY AND OTHERS.

patterns of relatedness among words in written discourse. Perilog's ability to deliver semantic and conceptual search results through an automated algorithm, without the need to rely on natural language processing or manually (or semi-manually) maintained categorization, follows directly from the theory of iconicity.

How it works

Perilog measures the degree of contextual association of large numbers of term pairs in text to produce network models that capture the structure of the text and, by virtue of Perilog's validated theory of iconicity, the structure of the domain(s), situation(s), and concern(s) expressed by the author(s) of the text. In fact, given alphanumeric representations of any other sequences in which context is meaningful—such as music or genetic sequences—Perilog can derive their contextual structure.

Operating on a document set (i.e., corpus) or a single document, Perilog creates a network model of contextu-

ally related words and phrases. When a user enters a keyword or key phrase search, Perilog creates a query network of “topical hubs,” based on the query words input by the user. Phrases may be of any number and length. Each phrase is represented by a network, and these networks are combined into a single query network.

By matching the phrase query network with document networks, Perilog's phrase search provides flexible and thorough phrase matching that is unavailable with other methods. Instead of the keyword search being limited to the query words alone, Perilog uses the relationships of keywords within their contextual associations to find documents in which those relationships are significant.

Key Features and Methods

- Text analysis
- Modeling
- Relevance-ranking
- Keyword and phrase search
- Phrase generation, and
- Phrase discovery

Opportunities for Partnership

Benefits

- Delivers more relevant search results, with fewer queries by the user, compared with other search engine technologies.
- Contextual relevance: Enables users to discover words, ideas and situational details that are contextually associated with a specific query.
- Intelligent search: Allows users to discover key themes in large document sets, with no prior knowledge of the documents.
- Efficient classification: Eliminates the time and expense associated with maintaining document categorization (i.e., ontology), delivering semantic and conceptual search results.

Applications

Perilog can enhance many search-related applications, including these:

- Large knowledge management and document retrieval systems, for legal research, market research, intellectual property asset management, claims management, etc.
- Life sciences and medical research
- Intelligence analyses
- Commercial search engines
- Contextual online advertising
- Airline flight safety databases

For more information and details about licensing this technology, contact William M. Toscano in the Entrepreneurial Initiatives Division of Ames at (650) 604-0894 or William.M.Toscano@nasa.gov. Please reference Case Number ARC-15088-1.

Please mention that you read about it in Technology Innovation.

Endothelium Preserving Microwave Treatment for Atherosclerosis

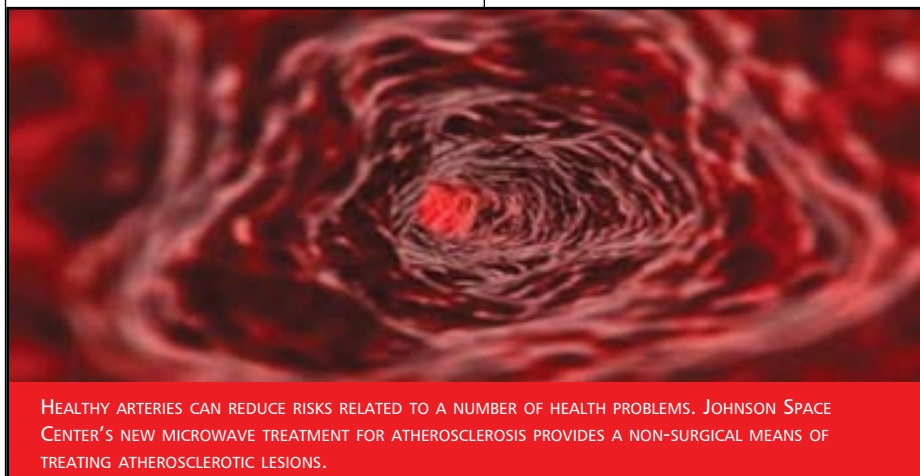
NASA seeks interested parties for the commercial application of an endothelium preserving microwave treatment for atherosclerosis, developed at Johnson Space Center. In theory, this technology provides for the non-surgical

Technology Details

Although millimeter-wave/microwave ablation has yet to be proven in tests on live animals, it offers the potential to significantly advance the state of the art. Indeed, after further testing, millimeter-wave/microwave ablation has the potential to be used by cardiologists during balloon angioplasty replacement procedures (PTCAs) or coronary catheterizations.

How it Works

In millimeter-wave/microwave ablation, electromagnetic energy would



repair of diseased coronary arteries by interventional cardiologists during coronary catheterization. Millimeter-wave/microwave ablation (essentially, heating by use of millimeter-wave and microwave electromagnetic radiation) is proposed as a means of treating atherosclerotic lesions. Because it is expected to be safer and more effective than traditional methods, millimeter-wave/microwave ablation soon could supplement or even supplant today's treatment choices.

be delivered via a catheter to a precise location in a coronary artery for selective heating of a targeted atherosclerotic lesion. Heating to controlled, customized temperature profiles could be used to treat lesions in the intima and media layers of an artery wall, yet the most superficial endothelial cell layer and the outer adventitial layer would be preserved. Preservation of the endothelial cell layer is necessary to prevent thrombotic, inflammatory and proliferative processes (restenosis), which complicate angioplastic procedures.

In millimeter-wave/microwave ablation, advantageous temperature profiles would be obtained by controlling the power delivered, the pulse duration and the frequency. For best results, the maximum temperature would be delivered at the center of an atherosclerotic lesion, with the temperature decreasing uniformly in all directions with distance from the center. The heating would favorably modify lipid-rich lesions that contain the inflammatory cellular infiltrates that are prone to rupture, and the rupture of which causes thrombotic artery occlusions (heart attacks).

The source would generate millimeter-wave or microwave power at a controlled level up to 10 W, with a pulse duration of 0.1 s - 10 s, controlled to within two percent. A chosen frequency 3 GHz – 300 GHz could be used; a separate source likely would be needed for each frequency. The catheter/transmission line would deliver the power to the antenna, which would focus the radiated beam so that most of the millimeter-wave or microwave energy would be deposited within the targeted atherosclerotic lesion. Because of the rapid decay of the electromagnetic wave, little energy would pass into, or beyond, the adventitia.

Benefits

- Millimeter-wave/microwave power source
- Antenna fits in a catheter
- Uses a transmission line in the form of a waveguide or coaxial cable
- Non-invasive
- Is an improved method to dilate

congested arteries without harming endothelial layer or healthy tissue

- Does not scar or damage blood vessel walls
- Requires less time to heat atherosclerotic lesions
- Can be used while blood continues to flow in the artery

Application

- Treatment for atherosclerosis

For more information and details about licensing for commercial applications this technology (please reference Case Number MSC-22724) and/or related microwave technologies within this portfolio, contact the Johnson Space Center Innovation Partnerships Office at (281) 483-3809, or jsc-techtran@mail.nasa.gov, or visit <http://technology.jsc.nasa.gov>.

Please mention that you read about it in Technology Innovation.

In Situ Health Monitoring of Piezoelectric Sensor

Available for licensing through NASA's John C. Stennis Space Center is a technology capable of performing *in situ* testing of dynamic piezoelectric transducers.

Background

On occasion, anomalies appear in the highly dynamic test data during rocket engine tests conducted at

Stennis. Each data anomaly occurring during a test program must be investigated and appropriate corrective action pursued before the test program can continue with subsequent testing. Due to condensed test schedules, generally only three days are allotted for identifying the cause of any anomaly and performing a corrective action.

In a typical problem occurring during this process, spurious signals appeared in eight accelerometer data channels, wherein the origin of those signals was unknown. It was thought that the spurious signals might have been caused by loose or broken accelerometers.

Stennis technicians were sent to remove the accelerometers from the test article and to check the mounting torque, resulting in the replacement of several transducers and costly delays. Only one of the accelerometers was identified as defective, and the cause was never conclusively pinpointed.

An *in situ* test would have determined if the transducers were operating properly or if they were in error. Often it is unclear whether anomalies in recorded signals are due to differences between the data acquisitions systems, differences between the transducers or a failed transducer, or whether everything is working correctly and the systems are accurately recording real events.

In an effort to enhance the facility capabilities, consideration was made to adding *in situ* test systems to existing *(continued on page 54)*

NASA'S IPP NETWORK

visit www.ipp.nasa.gov

NASA CENTERS:

- ARC – Ames Research Center
- DFRC – Dryden Flight Research Center
- GRC – Glenn Research Center
- GSFC – Goddard Space Flight Center
- HQ – Headquarters
- JPL – Jet Propulsion Laboratory
- JSC – Johnson Space Center
- KSC – Kennedy Space Center
- LaRC – Langley Research Center
- MSFC – Marshall Space Flight Center
- SSC – Stennis Space Center

ALLIED AND AFFILIATED ORGANIZATIONS:

- CAFE – Comparative Aircraft Flight Efficiency Foundation
- CASI – NASA Center for AeroSpace Information
- FLC – Federal Laboratory Consortium
- NTTC – National Technology Transfer Center
- SWF – The Spaceward Foundation
- TBMG – Tech Briefs Media Group
- USSF – United States Space Foundation



★ NASA Headquarters

● Innovative Partnerships Program Offices at each of NASA's 10 Field Centers represent NASA's technology sources and manage center participation in technology transfer activities.

■ Allied Organizations support NASA's IPP objectives.

★ Centennial Challenges Allied Organizations

National Aeronautics and Space Administration Innovative Partnerships Program (IPP) Network

NASA Headquarters

300 E Street, SW
Washington, DC 20546

Douglas A. Comstock
Director, IPP Office
Phone: 202/358-2221
E-mail: doug.comstock@nasa.gov

Jack Yadavish
Deputy Director, IPP Office
Program Executive, Partnership Development
Phone: 202/358-1981
E-mail: jyadavish@hq.nasa.gov

Charles E. Miller
Senior Advisor for Commercial Space, IPP Office
Phone: 202/358-2220
E-mail: charles.miller@nasa.gov

Andrew Petro
Program Executive, Innovation Incubator, IPP Office
Phone: 202/358-0310
E-mail: andrew.j.petro@nasa.gov

Carl G. Ray
Program Executive, Technology Infusion, IPP Office
Phone: 202/358-4652
E-mail: carl.g.ray@nasa.gov

Janelle Turner
Program Executive, Outreach, IPP Office
Phone: 202/358-0704
E-mail: janelle.b.turner@nasa.gov

NASA Field Centers

Ames Research Center
Moffett Field, California 94035
(see pgs. 18, 20, 25, 45, 48, 49)
Aviation Safety, Airspace Systems, Avionics and Software, Protection Systems, Space Radiation, Small Spacecraft, Information Technologies, Integrated Health System Management

David Morse
IPP Chief
650/604-4724
david.r.morse@nasa.gov

Dryden Flight Research Center
4800 Lilly Drive, Building 4839
Edwards, California 93523-0273

Aviation Safety, Atmospheric Research

Ron Young
IPP Chief
661/276-3741
ronald.m.young@nasa.gov

Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
(see pgs. 17-19)
Aviation Safety, Fundamental Aeronautics, Aeronautics Test Technologies,

Environmental Control and Life Support, Extra Vehicular Activity, Lunar Operations, Energy Generation and Storage, Protection Systems, Exploration Crew Health Capabilities, Spacecraft and Platform Subsystems, Space Communications and Navigation, Processing and Operations

Kathleen Needham
IPP Chief
216/433-2802
Kathleen.K.Needham@nasa.gov

Goddard Space Flight Center
Greenbelt, Maryland 20771
(see pg. 37)
Structures, Materials, Mechanisms, Sensors, Detectors, Instruments, Advanced Telescope Systems, Spacecraft and Platform Subsystems, Information Technologies, Space Communications and Navigation

Nona Cheeks
IPP Chief
301/286-5810
nona.k.cheeks@nasa.gov

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109
(see pg. 27, 37)
Sensors, Detectors, Instruments, Advanced Telescope Systems, Robotics, Space Communications and Navigation

Indrani C. Graczyk
IPP Manager
818/354-2241
indrani.graczyk@jpl.nasa.gov

Johnson Space Center
Houston, Texas 77058
(see pgs. 6, 8, 9, 12, 20, 26, 28, 40, 46, 50)
Sensors for Autonomous Systems, Environmental Control and Life Support, Extra Vehicular Activity, Lunar In Situ Resource Utilization, Lunar Operations, Thermal Management, Exploration Crew Health Capabilities, Space Human Factors and Food Systems, Space Radiation

David Leestma
IPP Chief
281/483-3809
jsc-techtran@mail.nasa.gov

Kennedy Space Center
Kennedy Space Center, Florida 32899
(see pgs. 42, 43)
Space Transportation, Processing and Operations, Launch Site Technologies

David R. Makufka
IPP Chief
321/867-6227
david.r.makufka@nasa.gov

Langley Research Center
Hampton, Virginia 23681-2199
(see pgs. 7, 20, 25, 36, 37)
Aviation Safety, Fundamental Aeronautics, Airspace Systems, Avionics and Software, Structures, Materials, Mechanisms, Sensors, Detectors, Instruments, Atmospheric Research

Elizabeth B. Plentovich
IPP Manager
757/864-2857 elizabeth.b.plentovich@nasa.gov

Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
(see pg. 26)
Structures, Materials, Mechanisms, Propulsion and Cryogenic Systems, Advanced Telescope Systems, Space Transportation

James Dowdy
IPP Chief
256/544-7604
jim.dowdy@nasa.gov

Stennis Space Center
Stennis Space Center, Mississippi 39529
(see pgs. 51, 54)
Space Transportation, Rocket Propulsion Testing, Remote Sensing Applications

Ramona Pelletier Travis
IPP Chief
228/688-3832
ramona.e.travis@ssc.nasa.gov

Affiliated Organizations
Working with NASA to advance the objectives of the Innovative Partnerships Program.

National Technology Transfer Center (NTTC)
Wheeling, West Virginia

Helping to meet NASA's technology needs through innovative products and services to facilitate infusion and partnership development.

Darwin Molnar
Vice President
dmolnar@nttc.edu
www.nttc.edu

United States Space Foundation
Colorado Springs, Colorado

Kevin Cook
Director, Space Technology Awareness
kevin@spacefoundation.org
www.spacefoundation.org

Federal Laboratory Consortium
Washington, DC

John Emond
Collaboration Program Manager
john.l.emond@nasa.gov
www.federalallabs.org

NASA Center for AeroSpace Information

Spinoff Project Office
Hanover, Maryland

Daniel Lockney
Editor/Writer
dlockney@sti.nasa.gov
daniel.p.lockney@nasa.gov

Tech Briefs Media Group
New York, NY

Joe Pramberger
Publisher
joe@techbriefs.com
www.techbriefs.com

Allied Organizations

Partnering with NASA to manage prize competitions for the citizen inventor.
(see pg. 2)

The Spaceward Foundation
Mountain View, CA
<http://www.spaceward.org/>

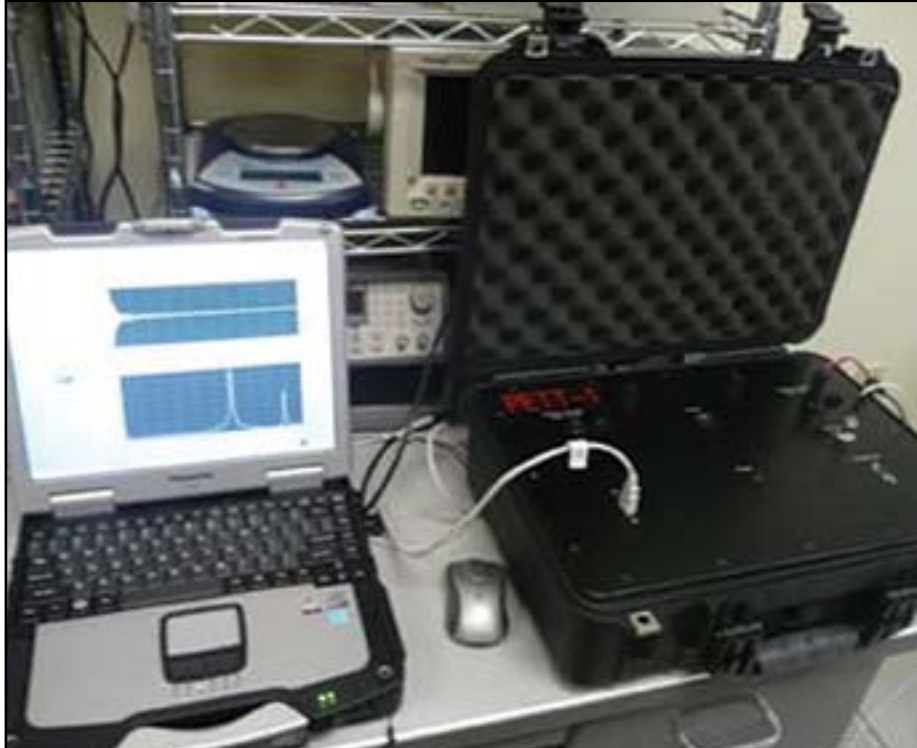
Comparative Aircraft Flight Efficiency Foundation
Santa Rosa, CA
<http://cafefoundation.org/>

The Innovative Partnerships Program (IPP) is being integrated into NASA's Office of the Chief Technologist (OCT) effective October 1, 2010. Like IPP has done, OCT will continue to complement the technology development activities of NASA's Mission Directorates. In addition, OCT will not only facilitate transfer of NASA developed technology for commercial application and other public benefit, but will also target its technology development efforts to provide solutions to some of the Nation's global challenges. The IPP program activities will continue under the OCT and will be expanded to have enhanced strategic importance both to the Agency and to the Nation. Accordingly, the next issue of *Technology Innovation* magazine will be published under the auspices of OCT.

Opportunities for Partnership

Technologies are available for licensing and joint development at each of the NASA Field Centers through their Innovative Partnerships Program (IPP) offices. Provided here are details on one of numerous available technologies. Read more about other new technologies each month in NASA TechBriefs (www.techbriefs.com), and for a comprehensive list, go to <http://ipp.nasa.gov>.

CREDIT: NASA



THE FIELD DEPLOYABLE *IN SITU* MONITORING SYSTEM REDUCES THE CHANCE OF USING FAULTY OR IMPROPERLY MOUNTED TRANSDUCERS.

dynamic instrumentation. However, adequate *in situ* test systems were unavailable, and the cost incurred from utilizing existing off-line testing systems remained.

Currently, signal simulators, shakers, static pressures simulators, and in-house calibration systems are readily employed for monitoring the instrumentation components. Any component with questionable performance, i.e., anomaly present, is sent out for extensive testing and high quality calibration. In addition, all the instrumentation sensors are put on a rotational calibration schedule to be

removed and sent off to a calibration laboratory.

The combination of recent events with data anomaly investigations, training, and experience from working with piezoelectric instrumentation systems led the inventors to create a device capable of *in situ* monitoring of piezoelectric transducers.

Piezoelectric transducers generate electric charges in response to mechanical deformation of the materials from which they are made. Pierre and Jacques Curie discovered this phenomenon in the 1880s. The first application of the piezoelectric effect was the detection of

submarines during World War I. They also demonstrated the inverse piezoelectric effect in which an electric field applied across a piezoelectric material deforms mechanically. However, the inverse piezoelectric effect has not been utilized to its full ability.

Applications

The Stennis technology available for licensing can be used for testing piezoelectric transducers while they are mounted to a structure. It also has the potential to detect structural changes in a test article. This kind of testing capability would reduce the chance of using improperly mounted transducers or faulty transducers.

Such a test method could also be used to monitor transducers between tests to detect any trends indicative of transducer failure or detachment. Utilizing this effect as an operational monitor has the potential to enhance the capabilities of piezoelectric instrumentation systems throughout industry. ■

For more information about licensing this technology, please call (228) 688-1929 or email ssc-technology@nasa.gov.

Please mention that you read about it in Technology Innovation.

**Your Guide to NASA's Technology Needs,
Partnership Successes and Partnership Opportunities**

TECHNOLOGY

INNOVATION

MAGAZINE FOR BUSINESS & TECHNOLOGY



**How to Partner
with NASA**



**NASA Technologies
Contribute to
Sustainability of
the Earth**



**NASA Encourages
Commercial Space
Industry**

For past issues or to register for your copy, go to
www.techbriefs.com/tech-exchange and www.ipp.nasa.gov/innovation.

National Aeronautics and Space Administration

Innovative Partnerships Program

Washington, DC 20546-001

www.nasa.gov

NP-2010-06-658-HQ

View Technology Innovation Online

and Register for
Additional Copies! Go to

<http://www.techbriefs.com/tech-exchange>

